Ernest Orlando Lawrence
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Final Safety Analysis Document for the Advanced Light Source (Rev. 3)

June 17, 1996

Approval Page for the ALS FSAD Rev. 3

	Signature	Date
AFRD Division Director Approve	C M Celata	6/13/96
ALS Operations Head Recommend	[illegible]	May 30, 1996
ALS Technical Safety Committee	Georgeanne Perdue	May 30, 1996

Ernest Orlando Lawrence
Berkeley National Laboratory

ADVANCED LIGHT SOURCE
Bldg. 80A • Room 102 • Ext. 7407

May 16, 1998

Memorandum

To: Ben Feinberg

From: Georgeanna Perdue GPerdue

Subj: Changes to the ALS FSAD Safety Envelope

On May 15, 1996, the Technical Safety Subcommittee reviewed and approved the three changes to the FSAD safety envelope. These changes and their rationale are as follows:

Increasing linac operating hours from 1095 to 8760 (hrs in one year)

Initiating occurrence:
The maximum exposure to a member of the general public occurs at the LBL site boundary. Prompt radiation relevant to the site boundary from operation of the linac comprises bremsstrahlung radiation and neutrons, which are produced during both normal and abnormal operating conditions.
Radiation is monitored by photon and neutron detectors in a station located 125 m south of the ALS building center at the LBNL site boundary. Radiation measurements are accumulated every ten minutes at this monitoring station.
All elements of the linac are enclosed in concrete shielding supplemented with lead and polyethylene in critical locations. The original calculation by R. -K.S. Sun of anticipated radiation levels at the site boundary was based on a shielding thickness of 2 feet of concrete and a cycle rate of 4PPS.
The shields that were actually installed are constructed of 4 foot concrete blocks with a tenth layer value that reduces the predicted dose rate outside the shield by a factor of 100.
Normal operations run at a cycle rate of 1PPS, which reduces the calculated amount of radiation by a factor of 4.
Recent analysis of the data taken from the ALS site boundary monitoring station that during the normal operation of the linac and booster measures 0.6 micorem per hour . Under these normal operating conditions, 4 bunches of electrons are accelerated each second of linac operation. So, the most extreme operating conditions, 5 bunches of electrons are accelerated each second(1.25 times as many electrons as the normal operating conditions, potentially producing 0.75 micorem per hour at the site boundary. At the 8760 hours in a year, the dose at the site boundary could be no more than 6.6 millirem per year. The administrative reporting level for site-boundary exposure is 10 mrem/year.

Consequences
Exposure at the site boundary to radiation from the shielded linac is not potentially lethal. Similarly, operation of the linac would have no major impact on the environment. From Table 4-4 of the ALS FSAD, it is judged that the consequence level at the site boundary of operating the accelerator is medium.

Probability
Because the accelerator would neither be operating without shielding nor without the other preventative/mitigating factors enumerated, which are basic ingredients in the design of the ALS, the Technical Safety Subcommittee concluded that the probability of exposure to radiation at the site boundary was extremely low. From table 4-5 of the ALS FSAD, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk
From the risk matrix the ALS FSAD table 4-6, a consequence level of medium and a probability level of extremely low result in site-boundary exposure risk of negligible for both normal and abnormal operation of the accelerator.

<u>Injecting with the Personnel Safety Shutter (PSS) open on BL3.1</u>

The Safety Envelope was changed to allow the PSS on beamline 3.1 to be open during injection. The FSAD had required that "A radiation safety shutter will close the hole during storage-ring injection . . . [to intercept] the lines of sight from inside the storage ring shield wall through the hole." Beamline 3.1 was designed specifically to mitigate the hazard from bremsstrahlung radiation to allow the PSS to be open during injection. The hole in the shield wall is below the plane of the storage ring and the synchrotron radiation is reflected through the hole. Bremsstrahlung radiation is not reflected by the mirror. Lead shielding inside the storage ring shield wall absorbs most of the bremsstrahlung radiation. Additional lead shielding and exclusions zones outside of the shield wall prevent line of sight to the storage ring. Bremsstrahlung ray-trace drawings (24E1586 and 24E1596) show all possible paths for bremsstrahlung radiation to come through the hole, and placement of shielding. Because of the above mentioned shielding, there is no hazard to personnel due to the beamline 3.1 PSS being open during injection.

<u>Changing units in Operations Envelope to conform to units in Safety Envelope.</u>

The safety envelope describes the limit on linac operation in terms of power. To make the relation between safety envelope and operations envelope clear, we changed the operations envelope to also describe the limit on linac operation in terms of power.

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SECTION 1. INTRODUCTION

This Final Safety Analysis Document (FSAD) for the Lawrence Berkeley Laboratory (LBL) Advanced Light Source (ALS) provides the necessary information and analyses to assure that the operation of the ALS can be conducted in a manner that will produce minimal risks to the health and safety of LBL employees, visiting scientists, and the public, as well as adequately protect the environment.

LBL Building 6, which was originally constructed to house the 184-Inch Cyclotron, was extensively remodeled and significantly enlarged for the ALS, a synchrotron-radiation source of x-ray and ultraviolet radiation. As a national user facility, the ALS will be open to visiting researchers and to LBL staff, who will use this radiation for basic and applied scientific and technological investigations, including structural and spectroscopic studies of gases, liquids, and solids.

1.1 Objective and Scope

This FSAD has been prepared in accordance with DOE Order 5481.1B Safety Analysis and Review System [DOE, 1986a] and SAN Management Directive 5481.1A SAN Management Directive: Safety Analysis and Review System [SF, 1989] to describe the physical and administrative controls that will ensure the safe operation of the ALS at LBL. DOE Order 5481.1B specifies that the FSAD shall "demonstrate that there is reasonable assurance that the DOE operation can be conducted in a manner that will limit risks to the health and safety of the public and employees and adequately protect Laboratory facilities and the environment."

The safety of the ALS is analyzed, reviewed, and documented at the FSAD level commensurate with its classification as a low-hazard facility. The safety analyses documented in this report demonstrate that ALS construction and operation are low hazard, as defined in SAN Management Directive 5481.1A, and will not present significant risks to the health or safety of on-site personnel or the general public. The risk of damage to the environment is also low.

As recommended by DOE Order 5481.1B, routine risks that are accepted without question by the vast majority of persons are not addressed in this document. Routine risks include traffic, machine shops that do not handle hazardous material, etc. This FSAD addresses those hazards that are not routinely encountered and accepted in the course of everyday living by the vast majority of the general public.

1.2 Facility Purpose

The ALS has been constructed in the Original Laboratory Site area of LBL on the site of the historic 184-Inch Cyclotron, which was decommissioned and disassembled. To make room for the ALS, the original cyclotron building (Building 6) was renovated, and a new 61,000 square-foot annular addition was constructed. The new building houses a 1.5-billion-electron-volt (1.5-GeV) electron storage ring and its associated injector complex for the generation of synchrotron radiation in the x-ray and ultraviolet regions of the electromagnetic spectrum. The radiation will be guided by up to 34 insertion-device and bend-magnet beamlines to experimental areas around the outside of the storage ring, with the possibility of 24 additional bend-magnet beamlines should they be required [ALS, 1986]. Each beamline may have more than one branch with separate experimental stations. In addition there is an electron beam line (the Beam Test Facility) for experiments involving the interaction of relativistic electron beam with plasmas, laser beams, and electromagnetic cavities.

Physicists, chemists, materials scientists, biologists, engineers, and other researchers will use the radiation to investigate the structure and composition of matter in its varied gas, liquid, and solid states. In addition to the radiation itself, the ALS will provide the necessary structures and support systems to carry out this type of research. Responsibility for the beamlines and the experimental equipment will be divided between the ALS and those doing the research, who will come from LBL, other DOE and federal laboratories, private industry, and universities.

1.3 Facility Description and Operation Summary

The ALS is a national user facility for the production of high-brightness and partially coherent x-ray and ultraviolet synchrotron radiation [ALS, 1986, 1989a]. A DOE-funded construction project with a total estimated cost (TEC) of $99.5 million, the ALS was completed on schedule in April 1993. Administratively, the ALS resides within the Accelerator and Fusion Research Division of LBL.

The ALS consists of a linear accelerator and a booster synchrotron (collectively known as the injector complex) and an electron storage ring, photon beamlines from insertion-device and bend-magnet sources, and associated experimental facilities. The ALS site covers a sizable, flat hilltop with good foundation conditions, centrally located within LBL. The original Building 6 provided approximately 20,000 square feet of floor space, which is being used for the linear accelerator and booster synchrotron. The storage ring, beamlines, and experimental facilities required the construction of a 61,000 square foot addition to Building 6. The addition consists of a 30-foot high steel-framed structure on new concrete footings with a heavy-duty concrete floor slab.

Included in the initial construction is the shell for a second floor of approximately 33,000 square feet for office and light laboratory space. The second-floor shell consists of basic structural elements (supporting members, floor, ceiling, and outer walls). Support facilities in the ALS building include a visitors' reception area, utility/storage space, and toilet facilities. Building 80 (adjacent to the Building 6 addition) houses the ALS control room, offices, electrical and mechanical shops, a conference area, and support facilities for beamline assembly at the ALS. It is accessible via a connecting door.

Operational activities fall into three categories: (1) generation of a 1.5-GeV electron beam by the linac and booster synchrotron and storage of the beam for several hours in the storage ring, (2) use of the x-ray and ultraviolet radiation by LBL and visiting scientists for the research activities described in Section 1.2, and (3) use of the Beam Test Facility to support R&D activities of the LBL Center for Beam Physics.

Operation of the injector accelerators and storage ring is accompanied by the generation of bremsstrahlung and neutron radiation for which shielding is provided. Exposure of LBL and visiting scientists to x-rays and other ionizing radiation is prevented by fixed in-place shielding, interlocked enclosures, and active radiation interlocks. The radiation shielding design is based on the dual design goals of limiting the radiation exposure to the general public to less than 10 mrem/year and limiting occupational exposure to ALS staff and users to less than 250 mrem/2000-hour worker year [ALS, 1986]. The shielding design allows the facility to achieve the DOE As Low As Reasonably Achievable (ALARA) radiation design objectives for new facilities [DOE, 1988a; EH&S, 1987; LBL, 1992a; LBL 1993a].

Use of the x-ray and ultraviolet radiation by LBL and visiting scientists may be accompanied by the introduction of flammable, toxic, biologically active, and radioactive materials in gaseous, liquid, and solid form. Volumes of hazardous materials will not exceed applicable building and fire code limits, and required venting and containment systems will be provided. In some cases where the hazardous material is the sample to be investigated and is present only in minute quantities, the material will be transported and studied only in sealed containers.

All beamline apparatus and experimental equipment, including lasers used in conjunction with synchrotron-radiation experiments, are subject to a mandatory safety evaluation before installation and will be operated in accordance with published codes and standards.

1.4 Conclusions of Assessment

The results of this analysis demonstrate that there is reasonable assurance that ALS operations, as controlled by the Safety Envelope developed in Section 6 in accordance with the Safety Analysis in Sections 4 and 5 of this FSAD, will be conducted in a manner that will limit risks to the health and safety of the public and employees to a "low level" and will adequately protect the environment. In particular, the results showed that the ALS facility can be operated within the risk envelope for low-hazard facilities as defined in SAN Management Directive 5481.1A.

Ernest Orlando Lawrence
Berkeley National Laboratory

ADVANCED LIGHT SOURCE
Bldg. 80 • Room 228 • Ext. 7725

March 26, 1998

Memorandum

To: Technical Safety Committee

From: Ben Feinberg

Subj: Risk Assessment for Safety Envelope Change

Any change to the Safety Envelope must be supported by an assessment that the change will not present significant risks to the health or safety of on-site personnel, the general public, or the environment. In this case, the pertinent potential risk is of exposure to synchrotron radiation. The assessment that there is no significant risk follows.

Initiating Occurrence

Exposure to synchrotron radiation can in principle occur for personnel in the beamline and experimental areas during operation of the accelerator.

Method of Detection

The active and passive monitoring systems include a substantial set of radiation monitors in the vicinity of the beamlines and experimental chambers which are designed to detect synchrotron radiation.

Preventive/Mitigating Features

Beamlines are designed to contain the synchrotron radiation within the vacuum chamber. Access to beamline and experimental areas where exposure to synchrotron radiation could occur is prevented by physical barriers that are interlocked or whose method of access precludes a radiation hazard. Interlocks are fail-safe, redundant, and testable. Enclosures are required to be constructed with locks that prevent disassembly. ALS Procedures require that (1) staff and visiting workers receive radiation safety training and (2) interlocks are tested as part of a scheduled maintenance program.

Consequences

Exposure to synchrotron radiation may cause injury or occupational illness to personnel. Using the Table 4-4 of the ALS FSAD, the consequence level is judged to be "low."

Probability

Exposure to synchrotron radiation would be possible if the beamline and/or endstation were poorly designed or constructed, disassembled or the protective interlock system failed when an attempt was made to pass through physical barriers blocking access. The revised ALS beamline review process ensures that design errors are reviewed by the appropriate personnel, and that construction errors are detected through a thorough, documented commissioning process. If the beamline were not intact, either the photon shutter and the personnel safety shutter in the beamline front end would be shut or storage-ring operation would be halted by the protective interlock system. If the end station were disassembled, the end-station personnel safety shutter would be shut by the protective interlock system or ALS Beamline Operator who provided the keys to allow disassembly would key off the beamline. Either case would automatically cause the personnel safety shutter to close. Because of the fail-safe, redundant, testable character of the interlock system, the probability of any of these events, using Table 4-5 of the ALS FSAD, is judged to be "low."

Risk

From the risk matrix of Table 4-6 of the ALS FSAD, a consequence level of "low" and a probability level of "low" result in a risk of "negligible."

ALS Safety and Operations Envelopes

Safety Envelope for ALS Accelerators, Beamlines, and Experiments

- Linac beam power: any combination of beam current, energy, and cycle rate that gives a beam power of 0.85 W (e.g., for the nominal operating parameters of 2×10^{10} electrons/cycle, 50-MeV electron energy, and 1-Hz cycle rate, the beam power is 0.16 W).
- Booster synchrotron beam power: any combination of beam current, electron energy, and cycle rate that gives a beam power of 8.25 W (e.g., for the nominal operating parameters of 16 mA or 2.6×10^{10} electrons accelerated and extracted/cycle, 1.5-GeV extracted beam energy, and 1-Hz cycle rate, the beam power is 6.2 W).
- Energy in storage-ring beam: any combination of stored current and electron energy that gives a total energy of 1000 J (e.g., for the nominal operating parameters of 400-mA stored current or 1.65×10^{12} electrons and 1.5-GeV electron energy, the energy in the beam is 395 J).
- A search-and-secure is carried out for each High Radiation Area (in which there is the potential for a whole body dose of 1 rem in any one hour) in the ALS building to assure that all personnel are excluded.
- At least one accelerator operator is on shift during accelerator operation.
- The personnel safety shutters that are an integral part of the bremsstrahlung collimation system or bremsstrahlung shield are closed during injection of beam into the storage ring.
- The bremsstrahlung shielding and exclusion zones are in place.
- In beamline areas, the VUV and soft x-ray radiation is contained within vacuum tubes and chambers.
- In experimental areas, the VUV and soft x-ray radiation is contained within vacuum chambers, within an interlocked hutch, or an enclosure whose method of access precludes a radiation hazard.
- Quantities of hazardous chemicals and materials in the ALS building do not exceed the 1988 UBC/UFC B-2 Exempt Aggregate Quantity.

LAWRENCE BERKELEY LABORATORY
Environment, Health and Safety Division
Mailstop 48-102 Ext 7067 FAX 7014

March 19, 1998

MEMORANDUM

TO: Ben Feinberg

FROM: Keith Gershon KG
General Science & Operations Support Group

SUBJECT: ALS Safety Envelope

Acting on behalf of the ALS EHS Manager, I convened a meeting of the ALS Technical Safety Committee on March 18, 1998 to examine a proposed change to the Safety Envelope. This change would allow the addition of an enclosure for protection from VUV and Soft X-ray radiation, whose design would preclude any undesired exposure, to the presently recognized methods of using vacuum chambers or interlocked hutches.

Attending were Alastair MacDowell, Rick Donahue, Howard Padmore, Ben Feinberg, and Keith Gershon. After evaluating the potential safety consequences, the committee approved this change and recommends that you submit it to DOE as necessary for notification purposes.

KG

cc: G. Perdue
encl: 1pg

REQUEST FOR CHANGES TO ALS SAFETY ENVELOPE

Requester	Request Date	Desired Completion Date
Ben Feinberg	3-18-98	3-31-98

System Affected:

ALS Experimental Areas.

Reason for Change:

This change will permit greater flexibility of experiment design and construction, with no compromise in the level of radiation protection.
A Technical Safety Committee has concluded that this change will not result in any negative impact on the health and safety of LBNL employees or the general public.

Description of Change:

Change the phrase, "The VUV and Soft X-ray radiation is controlled within vacuum chambers or within an interlocked hutch" to read,

"The VUV and Soft X-ray radiation is controlled within vacuum chambers, an interlocked hutch, or an enclosure whose method of access precludes a radiation hazard."

Safety Analysis Documentation (attach):

CHANGE APPROVED BY	DATE
[signature]	3/27/98.
External EH&S Reviewer E. Hengelman for Rick Donahue	3/27/98
Technical Safety Sub-Committee, Georgeanna Perdue [signature] for G. Perdue	3-20-98
ALS Division Director Brian Kincaid	3-27-98

SECTION 2. SUMMARY AND CONCLUSIONS

The ALS safety analysis was prepared in accordance with the guidance provided in DOE Order 5481.1B, Safety Analysis and Review System [DOE, 1986a]. A description of the methodology used in identifying hazards, analyzing credible accident scenarios, and assessing risks is summarized in Section 2.1. The hazard-event analyses themselves are summarized in Section 2.2. Conclusions and an assessment of the overall risk associated with ALS operations are discussed in Section 2.3.

2.1 Safety Analysis Methodology

The methodology used to perform the ALS safety analysis is shown in Figure 4-1 (page 4-2). The hazards analysis process began with a review of proposed ALS operations and research activities. Using the information obtained, a hazard analysis of proposed ALS activities was prepared. Potential hazards associated with the use of radiation sources, energy sources, hazardous materials, and from natural phenomena were studied.

Credible hazards with potential on-site or off-site consequences were then analyzed to assess associated risk. The analyses were based on a bounding event approach, where the most severe of each particular category of credible accident was analyzed to obtain worst-case results. Each event analysis included determining the initiating occurrence, possible detection methods, the safety features that would prevent or mitigate the event, the probability of the event occurring, and the possible consequences.

The probability estimates were made by the Technical Safety Subcommittee of the ALS EH&S Committee on the basis of the best professional judgment of the members of the subcommittee. The judgments were supported by statistics on occurrences at DOE accelerator facilities and by data accumulated on actual instances of exposure to radiation at LBL. In addition, site-specific design criteria for earthquakes were used in determining the probability of these events.

Using the guidance provided in SAN Management Directive 5481.1A [SF, 1989] for conducting safety analyses, the probability and consequences of each hazard were rated by levels. The overall risk associated with each specific hazard, and then for the facility as a whole, was determined using these rating levels and the risk matrix, also provided in SAN MD 5481.1A.

2.2 Hazard Event Analyses

The ALS hazards analysis identified potentially hazardous conditions that could occur during operations and during normal and abnormal operations. The analysis was used to determine the adequacy of the facility and systems designs and formed the basis for the development of necessary administrative controls.

Ionizing-radiation hazards at the ALS are due to loss of electrons at various stages of the beam acceleration and storage process and to the synchrotron radiation emerging from the insertion devices and bending magnets in the storage ring. Ionizing radiation is also produced by accelerator-related equipment, such as the klystrons that generate rf power. Hazards due to radiation exposure will be different for those working in the ALS facility and those outside the building in the general area. Hazards were analyzed for both types of personnel.

Analyses according to the methodology described was carried out for six categories of hazard events involving ionizing radiation and 17 categories of hazard events involving hazards other than ionizing radiation. Table 2-1 summarizes the results of the analyses.

2.3 Summary of Results

Operational activities planned for the ALS facility have been analyzed for hazard potential, and appropriate mitigation measures have been developed. The hazards analysis identified potentially hazardous conditions that could occur in the ALS during operations. Control measures were incorporated into the facility and systems design to mitigate most of the identified potential hazards. In other cases, administrative procedures were developed to ensure that facility operations could be conducted with a minimum of on-site and off-site consequences.

A risk analysis on six categories of hazard events involving ionizing radiation and 19 categories of hazard events involving hazards other than ionizing radiation, performed using a bounding event/worst-case approach, showed that the ALS facility can be operated within the risk envelope for low-hazard facilities as defined in SAN Management Directive 5481.1A.

Table 2-1. ALS Risk-Determination Summary.

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
Ionizing Radiation				
1	Exposure to Ionizing Radiation at the Site Boundary	Extremely Low	Medium	Negligible
2	Exposure to Ionizing Radiation outside the Accelerator Enclosures	Low	Medium	Low
3	Exposure to Ionizing Radiation inside the Accelerator Enclosures	Low	Medium	Low
4	Exposure to Synchrotron Radiation	Low	Low	Negligible
5	Exposure to Air Activation Products	Extremely Low	Medium	Negligible
6	Exposure to Ionizing Radiation from Sources Other than Accelerators	Low	Medium	Low
Fire Hazards				
1	Room Fire	Low	Low	Negligible
2	Room Fire Involving Radioactive or Toxic Materials	Low	Medium	Low
3	Equipment Fire	Medium	Low	Low

Table 2-1. ALS Risk-Determination Summary (cont.).

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
Hazardous Materials				
1	Uncontrolled Chemical Reactions	Extremely Low	Extremely Low	Negligible
2	Chemical Exposure	Medium	Low	Low
3	Cryogenic Temperature Exposure	Medium	Low	Low
4	Compressed Gas Explosion	Low	Medium	Low
5	Gas Explosion (Hydrogen, Oxygen, Acetylene)	Low	Medium	Low
6	Inhalation, Ingestion, or Dermal Exposure to Toxic or Carcinogenic Material	Extremely Low	Medium	Negligible
7	Oxygen Deficient Atmosphere	Extremely Low	Medium	Negligible
Electrical Hazards				
1	Electrical Shock	Low	Medium	Low
2	Nonionizing Radiation Exposure	Low	Medium	Low
3	Exposure to High Magnetic Forces	Medium	Low	Low

Table 2-1. ALS Risk-Determination Summary (cont.).

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
Laser Hazard				
1	Laser Light Energy Transfer	Low	Low	Negligible
Visible and Near-UV Light Hazard				
1	Exposure to Visible and Near-UV Light	Low	Low	Negligible
Ozone Hazard				
1	Ozone Exposure	Low	Low	Negligible
Seismic Hazard				
1	Earthquake	Low	Medium	Low
Vacuum Vessel Hazard				
1	Beamline Vacuum Vessel Implosion or Explosion	Extremely Low	Medium	Negligible
Industrial Accident				
1	Industrial Accident Involving Rotating Machinery or Falling Objects	Medium	Low	Low

SECTION 3. DESCRIPTION OF SITE, FACILITY, AND ORGANIZATION

3.1 Site Description

LBL is centrally located in the greater San Francisco Bay Area and is situated on the western slope of the Berkeley Hills. The Laboratory overlooks the Berkeley campus of the University of California and San Francisco Bay on land within the boundaries of, and leased from, the University of California. The following sections characterize the features of the ALS site [DOE, 1989; Keller, 1987; Harding-Lawson, 1983].

3.1.1 Site Location

The site for the ALS is within and adjacent to the original Building 6. This building, whose construction was begun in 1940 and completed in 1942, was the first of approximately 30 buildings to be constructed in the so-called Original Laboratory Site of LBL. The site is centrally located within LBL. It is close to electromechanical and mechanical technology machine shops and technician facilities, as well as the main LBL mechanical shops. The site is also adjacent to LBL's fire station and to the new Advanced Materials Laboratory (Building 2). Two adjacent older structures (Buildings 10 and 80) provide space for ALS activities during both the commissioning and operational phases. Of these, Building 80 is dedicated entirely to support of the ALS and is included in this FSAD. Building 10, in which only two rooms are used for user support laboratories, is not included. Figure 3-1 shows the LBL site and Figure 3-2 shows the ALS site.

3.1.2 Physiographic Setting

The Original Laboratory Site covers a sizable, flat hilltop area that commands a view of most of San Francisco Bay, including the San Francisco-Oakland Bay and Golden Gate Bridges, and of much of the surrounding urbanized areas of Alameda, western Contra Costa, San Francisco, San Mateo, and Marin Counties. The land around the site slopes downward, except on the northeast, where it slopes upward. The ALS site is toward the southwest corner of this area. Cut areas near the Advanced Materials Laboratory are supported by new retaining walls.

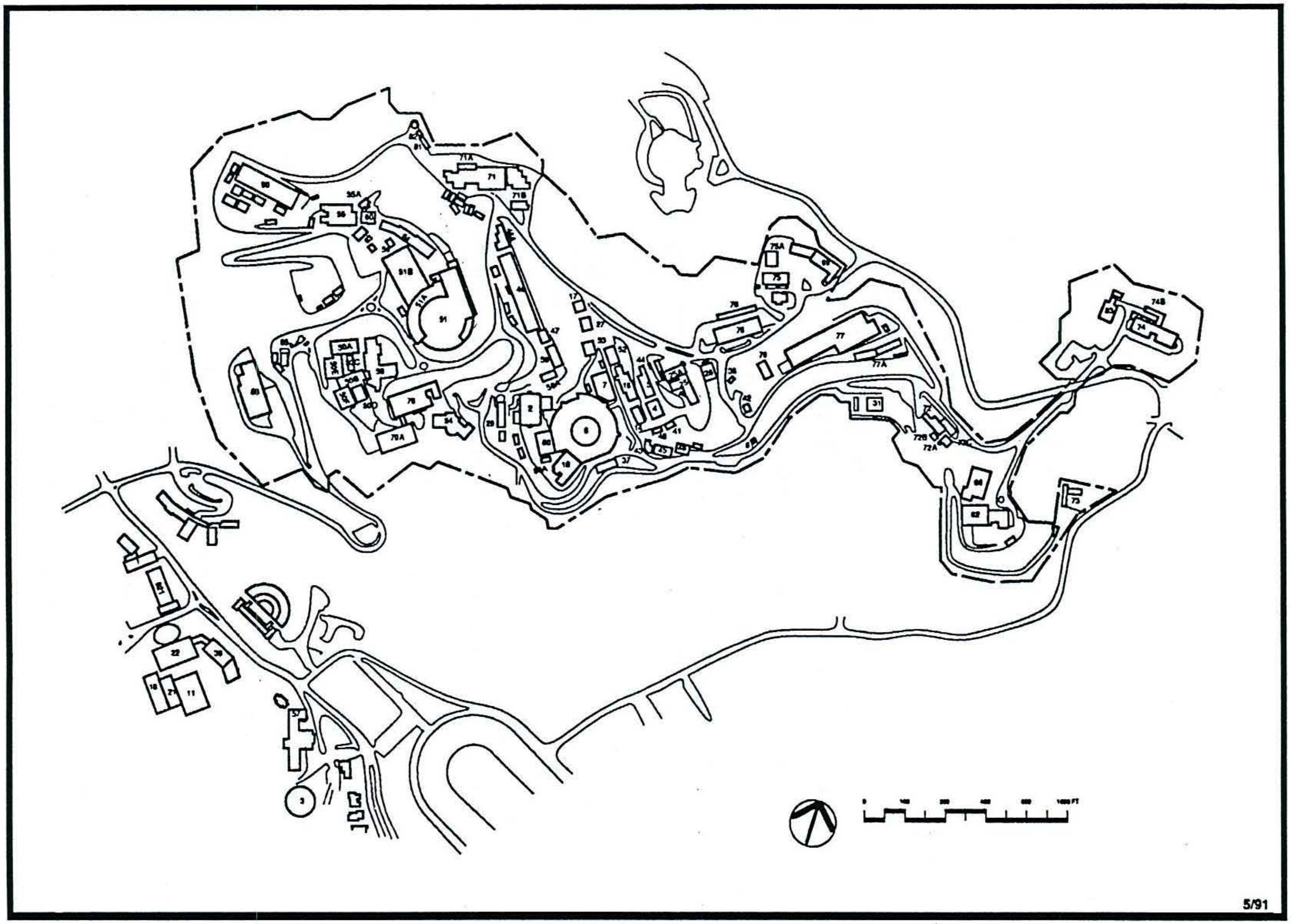


Figure 3-1. LBL site map.

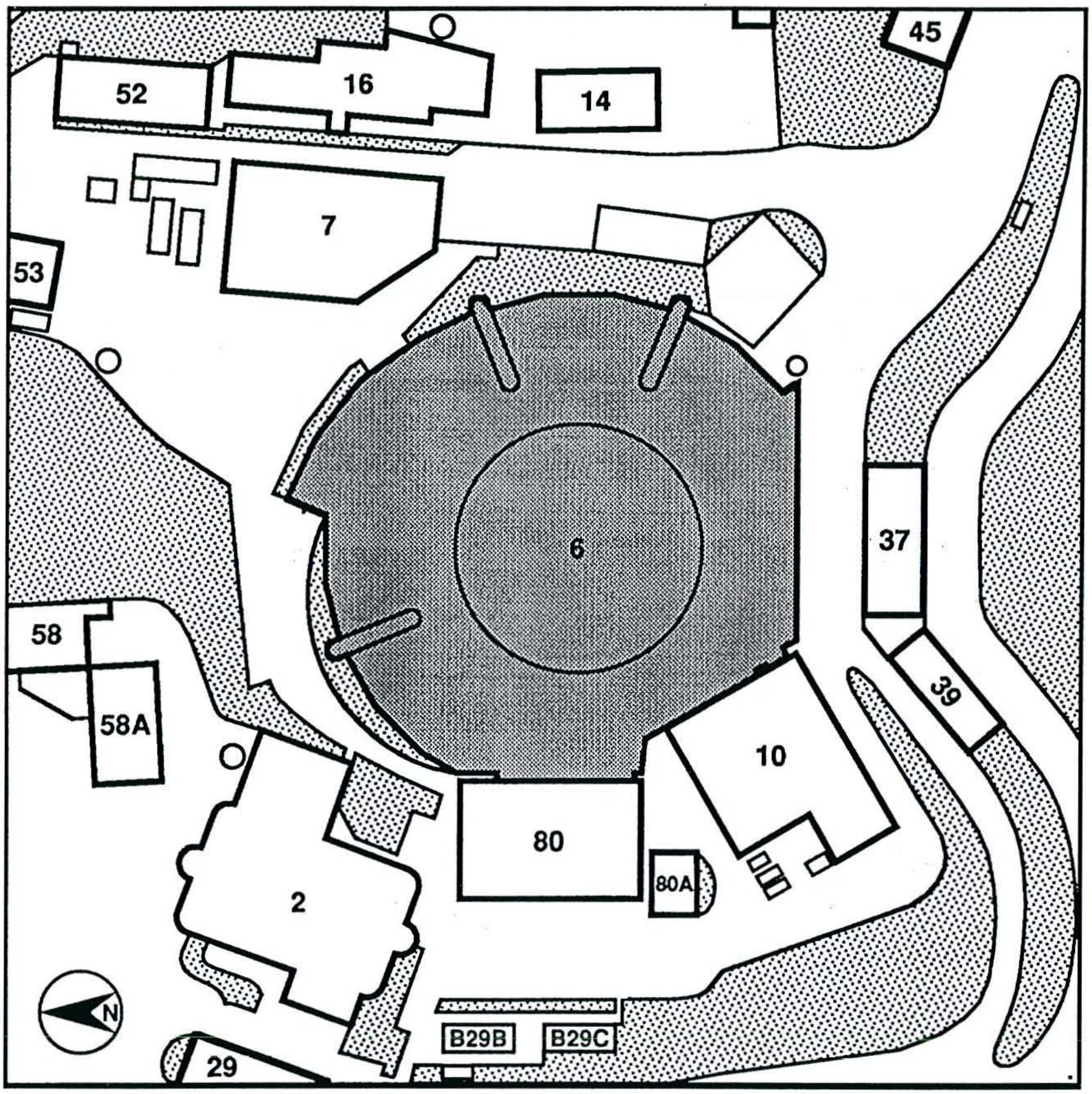


Figure 3-2. Advanced Light Source site, ground level.

3.1.3 Geology and Seismicity

The ALS site is located in the Berkeley Hills, which consist of a series of northwest-trending synclines and anticlines cut by numerous faults. The rocks are of marine, terrestrial, and volcanic origins. Differential erosion of soil and rock materials has created a diverse topography in the area. The bedrock formations are close to the surface and consist of volcanic basalt and andesite flows, pyroclastic tuff beds, and a sedimentary agglomerate (i.e. clayey siltstone).

Active faulting and crustal deformation continues in the area at the present time. The closest major fault lines are the Hayward Fault, which passes about 3500 feet to the southwest of the site, the Calaveras Fault, which passes 12 miles to the east of the site, and the San Andreas Fault, which passes 18 miles to the west of the site. The maximum credible earthquake postulated for the site would occur on the Hayward Fault and would have a Richter magnitude between 6.75 and 7.25 [LBL, 1992a, Chapter 23].

3.1.4 Soils

The bedrock at LBL is generally relatively weak and weathers deeply, thereby producing a thick colluvial soil cover. The bearing capacity of colluvial soil is relatively low, and foundation design usually requires consideration of the potential for shrinking and swelling. In addition, ancient land-slide deposits of variable dimensions are present throughout LBL, as are areas covered by landfill placed during site grading. The northwestern corner of the ALS site is one of these areas. Overall the foundation conditions at the ALS site are satisfactory.

3.1.5 Hydrology

The ALS site is located on a ridge that divides the Strawberry and Blackberry Creek Watershed areas on a naturally flat area that interrupts the otherwise upward sloping hillside. The site is approximately 890 feet above sea level, which precludes the ocean or water table from having effects on the site. In addition, storm sewers are provided with about 900 cfs capacity, so that buildup of rainwater from storms will not affect the site.

3.1.6 Climate

LBL is exposed to air flow from the Pacific Ocean through the Golden Gate and across San Francisco Bay. The marine influence keeps seasonal temperature differences relatively small. Sunshine for the year averages between 65 and 70 percent of the total insolation possible, and average daytime cloudiness is about the same in summer as in winter. Except for laboratories with special temperature stability requirements, LBL buildings are generally not air conditioned.

3.2 Site and Facility Demography

In 1992, LBL had approximately 2690 full-time employees and 895 part-time employees (mostly students or staff with joint appointments on the UC Berkeley campus), as well as more than 1615 guest scientists.

During operation of the ALS, approximately 150 staff will be required to support and operate the facility. In addition, at initial operation, about 50 persons (users), mostly visitors from outside LBL, will use the ALS experimental facilities. Ultimately, when 34 beamlines are fully developed, a maximum of about 150 users will be on site at any one time, of whom about 10 percent will be LBL employees.

3.3 Facility Description

The ALS is a national user facility primarily for the production of high-brightness and partially coherent x-ray and ultraviolet synchrotron radiation. There is also a Beam Test Facility for the investigation of the interaction of relativistic electron beams with plasmas, laser beams, and electromagnetic cavities. The ALS facility consists of an accelerator complex, a complement of beamlines and associated experimental areas, and a building (Building 6) to house this equipment. When the second floor of Building 6 is completed to provide light-laboratory and office space to users, this FSAD will be amended or an appendix added. The following sections provide a description of the ALS layout, the accelerator complex, the beamlines, the experimental areas, as well as utility systems. Safety systems are described in Sections 4 and 5.

3.3.1 Facility Layout

The ALS is located in the Building 6 area of the LBL site. The original Building 6 housed the 184-Inch Cyclotron, which has been removed (except for the magnet yoke). The original Building 6, which was roughly circular with a high, domed roof, provides approximately 20,000 square feet of floor space. This space is being used for the linear accelerator and booster synchrotron. The storage ring, beamlines, and experimental facilities required the construction of a 61,000 square foot addition to Building 6. Support facilities for operations personnel include a visitors' reception area, utility/storage space, and toilet facilities. Figure 3-3 shows the ALS facility layout. Figure 3-4 shows the elevations of the ALS building.

The 30-foot height of the addition offers the possibility of 33,000 square feet of office and light-laboratory space on a future second-floor structure over the experimental areas. To facilitate this option, the addition incorporates the basic structure (supporting members, floor, ceiling, and outer walls) of a future second floor.

Buildings 10 and 80 immediately adjacent to the ALS have been modified only to the extent of window and door removals and their replacement with matching fire-rated wall materials where they are common with the new-addition walls. There is a seismic gap between the ALS and these buildings. The Building 6 area is surrounded on three sides by roadways and service-vehicle parking. Roadways around the site have been improved and some close-in parking has been provided.

Included in this FSAD, Building 80 is dedicated to ALS activities and houses the ALS control room, staff offices, electrical and mechanical shops, a conference area, and support facilities for beamline assembly at the ALS. This building, which predates the ALS, comprises a basement, a main floor, and a mezzanine.

3.3.2 Utilities

The primary water supply for LBL is provided by the East Bay Municipal Utility District (EBMUD). Natural gas and electricity are provided by Pacific Gas and Electric Company (PG&E).

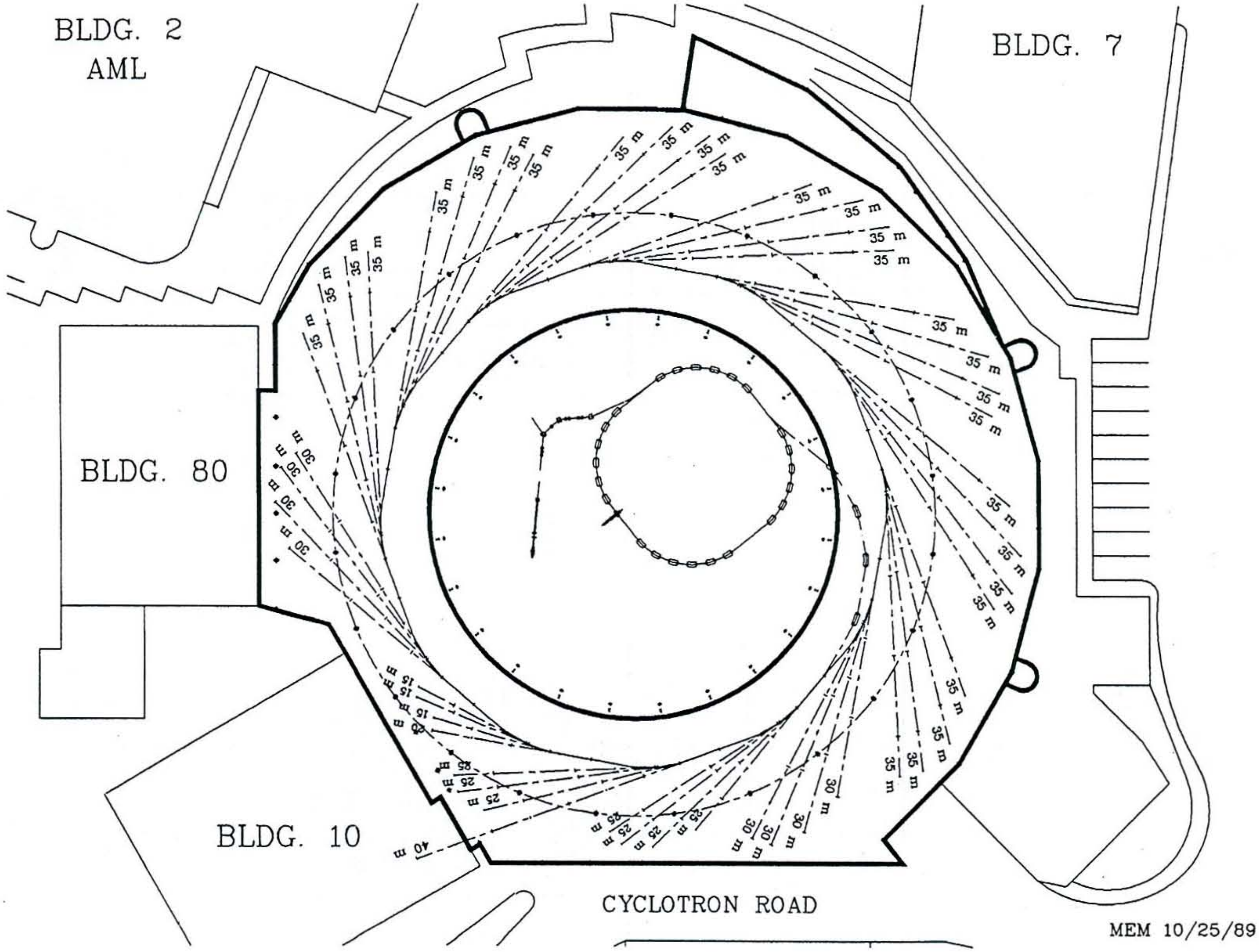


Figure 3-3. Layout of the Advanced Light Source facility showing the linac, booster synchrotron, electron storage ring, and photo beamlines within the expanded Building 6.

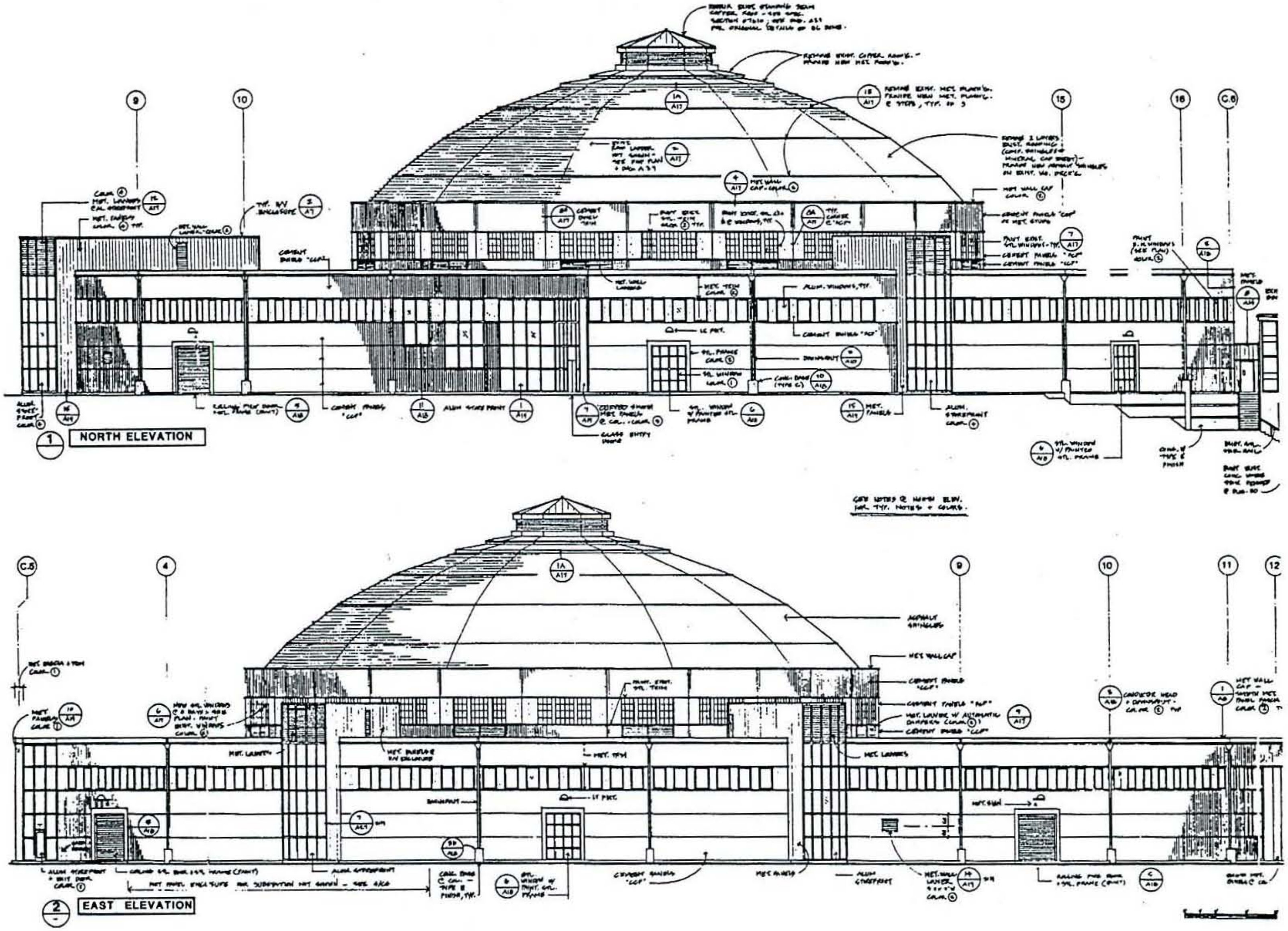


Figure 3-4. Elevations of the Advanced Light Source facility.

EBMUD supplies water to LBL primarily from large-capacity reservoirs in the Sierra Nevada foothills. Water is transported via 90 miles of aqueducts to five local reservoirs. Reservoirs nearest LBL are Shasta Reservoir with a capacity of 2,274,000 gallons serviced by a 12-inch pipe and Berkeley View Reservoir with a capacity of 4,051,000 gallons serviced by an 8-inch pipe. The EBMUD system supplies 20 communities with 1.1 million people in a 317 square-mile service area. Average use is 219,000 million gallons per day. LBL uses approximately 10,000 gallons of water daily.

LBL's sanitary sewers connect to the City of Berkeley system, which, in turn, terminates at a sewage treatment plant in Oakland. The LBL storm drains empty into Blackberry and Strawberry Creeks, which flow into the City of Berkeley system and then into San Francisco Bay. The City of Berkeley is currently in its fifth year of a 20-year rehabilitation program to modernize and increase capacity of the sanitary-sewer drain system. The primary treatment capacity is 290 million gallons per day. Secondary treatment capacity is 168 million gallons per day. Typical daily treatment flows to the system are 90 million gallons per day. EBMUD is in the midst of a five-year program to construct additional wet-weather facilities to handle the expected increases from contributing communities. With the new facilities the peak wet-weather treatment capacity will be 415 million gallons per day. With the new retention capacity, a total flow in the sewer system of 775 million gallons per day during storms will be accommodated.

PG&E supplies both firm and interruptible power to LBL. PG&E serves 48 counties in California with a population of 11 million and has a system-wide generating capacity of 21,700 MW. The East Bay service region of PG&E has a peak demand of 2,907 MW and consumed 14,382 billion kW-hours of electricity in 1988. LBL had a peak demand of 27 MW and consumed 100 million kW-hours of electricity in 1988. LBL has its own 60-MW substation. PG&E has ample capacity to meet anticipated demand for the foreseeable future.

Major electrical ALS site improvements include the installation of a new 12-kV transformer yard. The transformers are low-loss, fan-cooled, oil-filled units, and the underground feeders are double-ended to allow nondisruptive equipment maintenance. The total power requirement for the ALS and experimental apparatus is estimated at 7.2 MVA, and about 1.6 MVA is required for other LBL facilities sharing the same substation. The system is designed for 12.5 MVA, giving a 30% margin for future capacity.

At the ALS, electrical power at 480 V is distributed to switchboards inside the new addition and then to 480-V process loads and 277-V area-lighting loads. Local step-down transformers are used for loads requiring lower voltage. Cranes, heating and ventilating equipment, pumps, and miscellaneous motor loads are supplied by motor control centers. High-pressure metal-halide lighting has been provided and enhanced by task lighting where appropriate. A 300-kVA emergency generator has been installed to provide emergency power to critical ALS systems. Communication is provided by a telephone system, a closed-circuit intercom in the tunnels that house the accelerators, and a local building-paging system.

Utilities provided within the facility include low-conductivity water, compressed air, dry nitrogen, natural gas, industrial cold water, a sanitary sewer, and high-pressure fire-protection water mains. The linac, booster, and storage-ring tunnels are provided with low-conductivity water and dry nitrogen. Access to the tunnels is provided by utility trenches located at intervals around each ring.

3.3.3 Ventilation and Thermal Stability Systems

The heating and ventilating system is designed to maintain a uniform 75° F temperature in the entire building and to provide forced-air circulation during the summer. Certain areas will be temperature-controlled to ±1° C as explained in the next paragraph. Exhaust fans will be used to ventilate the tunnel areas.

Guiding the high-brightness radiation generated by the ALS through monochromators and onto samples located tens of meters from the storage ring requires exceptional stability on the part of storage-ring structures, the stored electron beam, and the experimental equipment. A major study of stability issues has showed that a 1° C temperature change perturbs the position of the electron beam in the storage ring by 1 standard deviation (σ), but stability to 0.1 σ is needed. A layered stability-control strategy was adopted that consists of kinematic mounting for mechanical stability, temperature control of the storage ring, beamlines, and experimental areas to ±1° C to bring motion within range of the electronic feedback system that controls the electron orbit.

To achieve temperature control of the storage ring and the experimental areas, a new chilled-water plant and air-conditioning system was added to the scope of the ALS project [Keller, 1990]. The chiller plant will supply chilled water necessary for air conditioning. A separate, two-story, reinforced concrete building of about 6,300 square feet (35 feet by 92 feet) is being constructed south of the ALS. The chiller plant consists of 6-MW cooling tower, chiller units, pumps, electrical equipment, and associated piping. The building provides space for an additional cooling tower and chillers.

Thermal stability in the storage-ring enclosure is accomplished through the use of chilled-water fan-coil units on the walls of the storage ring, which provide cooled air to the storage ring. Thermal stability in the experimental areas is accomplished by means of chilled-water cooling coils in the ALS roof-top air-conditioning units, which provide cooled air to the building ducted-air-distribution system. Terminal reheat coils provide final control. Each fan-coil unit, roof-top unit, and reheat-coil has a temperature sensor with associated valves and controls to maintain final building temperature at 75° F ± 2° F.

3.3.4 Accelerator Systems

As a third-generation synchrotron source, the ALS is based on the use of an electron storage ring specifically designed to have a very low emittance and several long straight sections containing insertion devices (wigglers and undulators). The combination of a very low emittance storage ring with optimized undulators makes possible the generation of radiation with a spectral brightness that is increased by a factor of 20 or more (depending on the spectral region) over that of existing, second-generation sources.

The ALS accelerator complex consists of a 50-MeV electron linear accelerator, a 1.5-GeV, 1-Hz booster synchrotron, and an electron storage ring optimized to operate at 1.5 GeV. The linac and booster are located inside the storage ring to avoid interference with user beamlines and to make best use of the layout of the original building.

The ALS linac is a conventional constant-impedance structure operating at 3 GHz (S-band) with two accelerating sections. The linac is fed by a 120-kV electron gun and bunching system that forms single S-band electron bunches with a charge of greater than 2 nC per bunch. All components of this system are housed in a concrete enclosure in the center part of the ALS building.

The linac injects electrons into a 1.5-GeV, 1-Hz booster synchrotron, from which they are extracted after acceleration for transfer into the storage ring. The booster has a 75-meter circumference and a missing-magnet FODO lattice with four-fold symmetry. The 1-Hz repetition rate permits filling of the storage ring to its nominal operating current of 400 mA in less than five minutes. Like the linac, the booster has been installed in a concrete tunnel in the area of the ALS building under the dome.

The storage ring is designed as a third-generation synchrotron-radiation source with a small natural emittance and long, dispersion-free, straight sections for insertion devices. Performance characteristics of the ALS are determined primarily by the design of the storage ring magnet lattice—the arrangement of bend and focusing magnets in the ring. The ALS lattice is optimized for the use of insertion devices. The magnet lattice contains 12 identical segments (superperiods), each of which is an achromatic arc comprising three combination gradient-bend magnets, six quadrupole focusing magnets, and four sextupole magnets in the triple-bend achromat arrangement (TBA). The storage ring has a design horizontal emittance of 3.5 nm-rad when operating at 1.5 GeV. Although the normal storage ring operating energy is 1.5 GeV, the ring is capable of operating over the range from 1 to 1.9 GeV. For operation at or below 1.5 GeV, the beam is injected into the storage ring at the operating energy (full-energy injection). For operation above 1.5 GeV, the beam is injected at 1.5 GeV and further accelerated in the storage ring. Table 1 lists the major parameters of the storage ring [ALS, 1989a].

On its way around the storage ring, the electron beam travels through 12 monolithic, machined-aluminum vacuum chambers (one for each arc), which will maintain the base pressure in the storage ring to about 0.1 to 1 nTorr, and 12 straight sections connecting the arcs. Of the 12 straight sections, one is occupied by injection hardware and one by two 500-MHz rf cavities, leaving 10 straight sections available for undulators and wigglers up to 4.5 m in length. Each arc of the storage ring is fitted with four bend-magnet ports that can be used to access bend-magnet radiation. Of the maximum of 48 ports, 24 are so-called prime ports with smaller vertical beam sizes that will be developed first.

Table 3-1. Main Parameters of the ALS Storage Ring.

Beam energy [GeV]	
Nominal	1.5
Minimum	1.0
Maximum	1.9
Circumference [m]	196.8
Beam current [mA]	
Multibunch	400
Single bunch	8
Beam emittance, rms [nm·rad]	
Horizontal	<10
Vertical	<1
Relative rms momentum spread	
Multibunch	8.0×10^{-4}
Single bunch	13.0×10^{-4}
Nominal bunch duration, FWHM [ps]	30-50
Radiation loss per turn [keV]	92
Length available for insertion devices [m]	4.5

The ALS produces electron beams that are bunched rather than continuous. The storage-ring rf system has a frequency of 500 MHz, so the spatial separation between bunches is 0.6 m and the temporal separation is 2 ns. The storage-ring lattice, the rf system, and the impedance of the vacuum-chamber hardware determine the length (spatial and temporal) of the bunches. For the ALS at the nominal current of 400 mA, the predicted full-width-at-half-maximum (FWHM) value of the bunch length is 35 ps. To avoid trapping positive ions in the potential well of the negatively charged electron beam, the multibunch mode with a 400-mA current will have 250 consecutive bunches, followed by a gap of 78 empty buckets. For particular experiments—for example, those involving time-of-flight measurements—it can be advantageous to have only one or a few circulating electron bunches in the storage ring. In the few-bunch mode, the nominal current per bunch will be 7.6 mA and the bunch length (FWHM) is predicted to be 55 ps, although still larger bunch currents may be tolerated. For a single pulse, the repetition rate would be the circulation time of the beam, 656 ns.

Multibunch Mode

In the multibunch mode, the electron gun (operating at 120 kV) produces a string of pulses, each about 2 ns long, separated by 8 ns (corresponding to 125 MHz). The number of pulses in this string can be varied between 1 and 12, giving a "macro-pulse" length of 2 to 100 ns. Before entering the linac, the pulses are compressed from 2 ns to 0.2 ns by the action of two sub-harmonic bunchers, operating at 125 MHz and 500 MHz. This operation ensures efficient capture of electrons in the linac. The 50-MeV beam is then transferred into the booster synchrotron by single turn, on-axis injection by means of a full-aperture kicker magnet. After acceleration to 1.5 GeV, the electron beam is extracted, again in a single turn, and transferred to the storage ring, where it is captured in a 500-MHz accelerating structure. This highly efficient acceleration/capture process is repeated until the required current is accumulated in the storage ring. It is anticipated that about 120 cycles (at a rate of 1 Hz) will be required to reach 400 mA of stored current.

Few-Bunch Mode

In the single- or few-bunch mode, the electron gun produces a single pulse, rather than multiple pulses. The transfer and acceleration processes are then identical to those used in the multibunch mode. The timing system for the accelerators is designed such that the single pulse can be placed at any point around the circumference of the storage ring. In this situation the current accelerated in the booster will be about one-tenth that in the multibunch mode, and filling times are anticipated to be about 0.3 mA per cycle per bunch. Therefore, about 30 cycles (at a rate of 1 Hz) are required to fill each bunch to 8 mA.

After filling, the injection system is turned off and the stored beam is allowed to decay naturally. After the decay process has reached the level where the beam must be replenished, the remaining beam is dumped by turning off the storage-ring rf system and then refilling takes place as described above. The design value of the beam 1/e-lifetime is about 6 hours. Refilling is planned to be done at 8-hour intervals.

It is planned to operate the storage ring 24 hours per day (three 8-hour shifts) five days per week.

Beam Test Facility

The Beam Test Facility (BTF) makes use of the ALS linac. Between storage-ring filling operations, the 50-MeV linac electron beam can be transported via a transport line through the wall of the linac cave into an experimental vault adjacent to the linac cave [Leemans et al. 1993]. The maximum energy and current of the linac for BTF operation are identical to those of the linac for storage-ring injection.

3.3.5 Insertion Devices

There are 10 storage-ring straight sections available for insertion devices (undulators and wigglers). The magnetic structure of an insertion device consists of a linear array of north-south dipoles of alternating polarity. The normal vertical orientation of the dipoles causes relativistic electrons of energy E to undergo a nearly sinusoidal electron trajectory of period λ_u in the horizontal plane, causing the emission of synchrotron radiation.

Undulators can provide radiation of unparalleled spectral brightness, with a significant degree of spatial coherence. The spectrum of undulator radiation consists of a series of narrow peaks at a fundamental photon energy and its harmonics. By varying the undulator magnetic field, which decreases as the gap between the poles of the undulator increases, the photon energy of the fundamental and the harmonics can be scanned. At the ALS, it is planned to use the third and fifth harmonics of the undulators to extend their spectral range to higher photon energies (2.5 keV) than can be reached with the fundamental alone (0.55 keV).

For experiments at the ALS requiring x-rays with higher photon energies than those obtainable from an undulator, a wiggler is needed. A wiggler produces a broadly peaked (or "white") spectrum of x-rays, which is spread into a relatively wide fan of radiation emerging from the insertion device. The ALS wiggler has a critical photon energy ε_c , defined as the photon energy above which half the total power is radiated. At the high-energy end of the broad wiggler spectrum, the flux drops rapidly but is still one-tenth of its maximum value at photon energies near $4\varepsilon_c$, so that the ALS spectral range extends into the hard x-ray region near 10 keV, although the increased spectral range comes at the expense of reduced brightness, as compared to that of undulator radiation. By comparison, the critical photon energy of the ALS bend magnets is 1.56 keV.

ALS Insertion Devices

In collaboration with the user community, a basic complement of insertion devices has been designed (Table 3-2). There are three types of undulators (U8.0 with an 8-cm period, U5.0 with a 5-cm period, and U3.9 with a 3.9-cm period) and a wiggler (W16.0 with a 16-cm period). The undulators span the spectral range available when the storage ring is operating at 1.5 GeV. Figure 3-5 shows the spectral brightness of radiation from the three undulators, the wiggler, and the bend magnets.

Conceptual Design Reports have been completed for the undulators U5.0 [ALS, 1989b] and U8.0 [ALS, 1990a] and for wiggler W16.0 [ALS, 1991a]. Three undulators, two U5.0s and one U8.0, have been constructed at LBL. All ALS insertion devices, whether constructed at LBL or outside, will have similar designs and operational performances. Figure 3-6 reflects a philosophy of generic design, whereby the major components of all insertion devices share similar designs—the objectives being reduced engineering and fabrication costs and simplified maintenance. The goals of very high brightness and useful fifth-harmonic output from the undulators impose unusually tight tolerances on the magnetic-field quality and thus on the mechanical structure of the undulators.

The major subsystems of the insertion devices are (i) the magnetic structure itself, which includes the hybrid pole assemblies mounted on pole mounts that are attached to the backing beams; (ii) the support and drive system, which includes the framework for supporting the magnetic structure and the mechanism for opening and closing the magnetic gap; and (iii) the vacuum system, which includes a vacuum chamber and its associated pumping system.

The U8.0 device has 55 periods, each of length 8.0 cm, and a total length of 4.6 meters. By using the third and fifth harmonics, as well as the fundamental, the spectral range 12–2100 Å (6–1000 eV) can be covered. To reach the lowest energy in this

Table 3-2. Parameters for ALS Insertion Devices.

Name	Period (cm)	No. of periods	Photon Energy range (eV)[a]	Critical energy (keV)
Undulators				
U8.0	8.0	55	5.4–220[b] [16.2–660] [27–1100]	–
U5.0	5.0	89	52–380 [156–1140] [260–1900]	–
U3.9	3.9	115	169–500 [507–1500] [845–2500]	–
Wiggler				
W16.0	16	16	–	3.1

[a]The photon energy range of the fundamental and of the third and fifth harmonics (shown in brackets) as the deflection parameter K decreases from its maximum value to approximately 0.5, when the electron-beam energy is 1.5 GeV.
[b]Below about 8 eV in the fundamental, the peak field in undulator U8.0 exceeds the bend-magnet field and may affect storage-ring operation.

range requires an effective field B_{eff} of 1.3 T at the minimum gap. The U5.0 device has 89 periods, each of length 5.0 cm, and a total length of 4.6 meters. By using the third and fifth harmonics, as well as the fundamental, the spectral range 8–240 Å (52–1500 eV) can be covered. To reach the lowest energy in this range requires an effective field B_{eff} of 0.837 T at the minimum gap.

The design requirements for the W16.0 wiggler were determined primarily by the user community. The central goals are to provide an on-axis peak critical energy of 3.1 keV and to distribute the radiation over a fan width of 16 mrad. The resulting device has 16 periods, each of length 16.0 cm, and a total length of 2.9 meters. The operating range of photon energies extends from below 1 keV to beyond 10 keV.

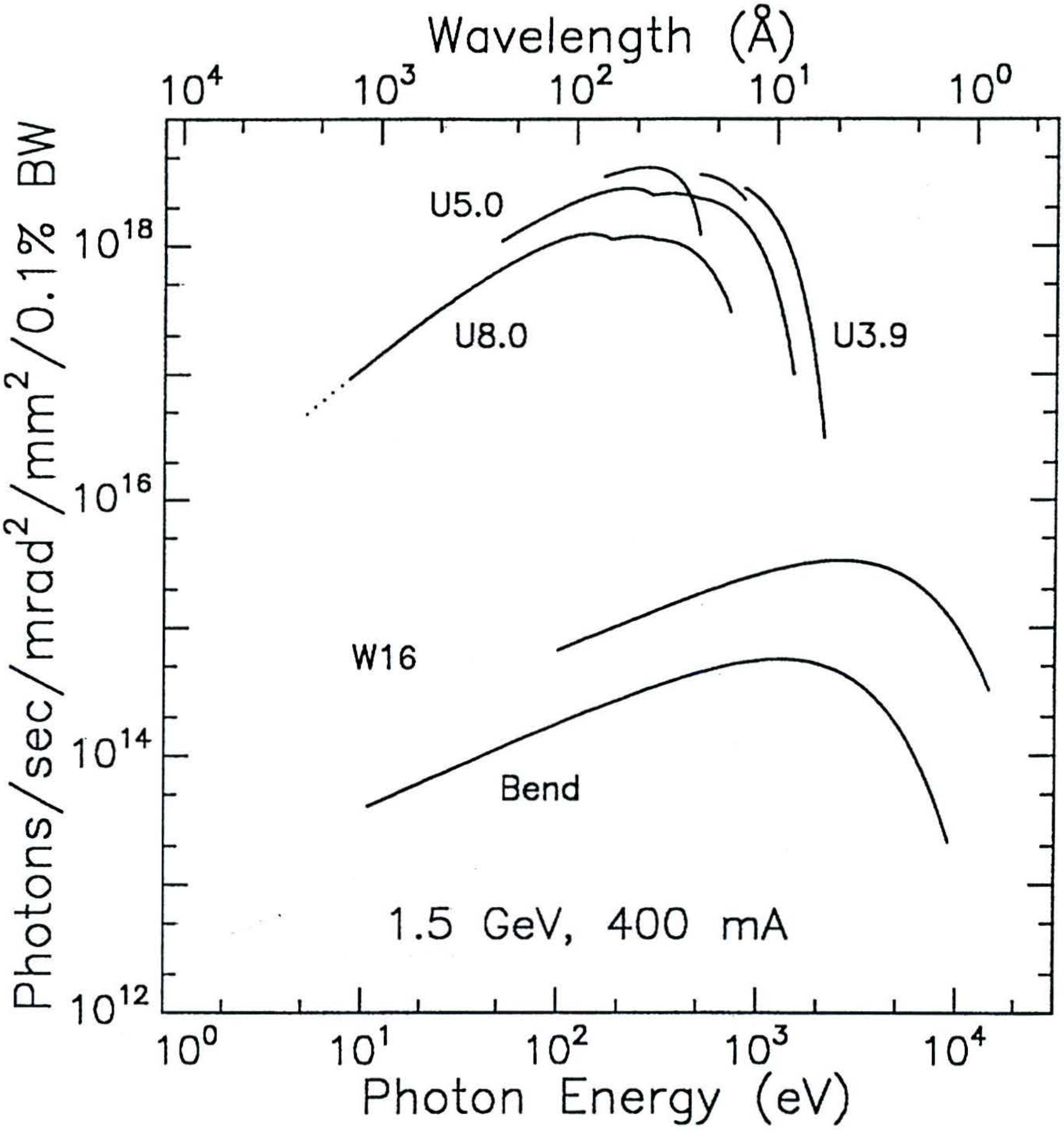


Figure 3-5. Spectral brightness as a function of photon energy for the three undulators and one wiggler described in Table 3-2, together with the ALS bend magnets. Each undulator curve is the locus of narrow peaks of radiation, tuned by altering the undulator gaps, and represents the envelope of the first, third, and fifth harmonics.

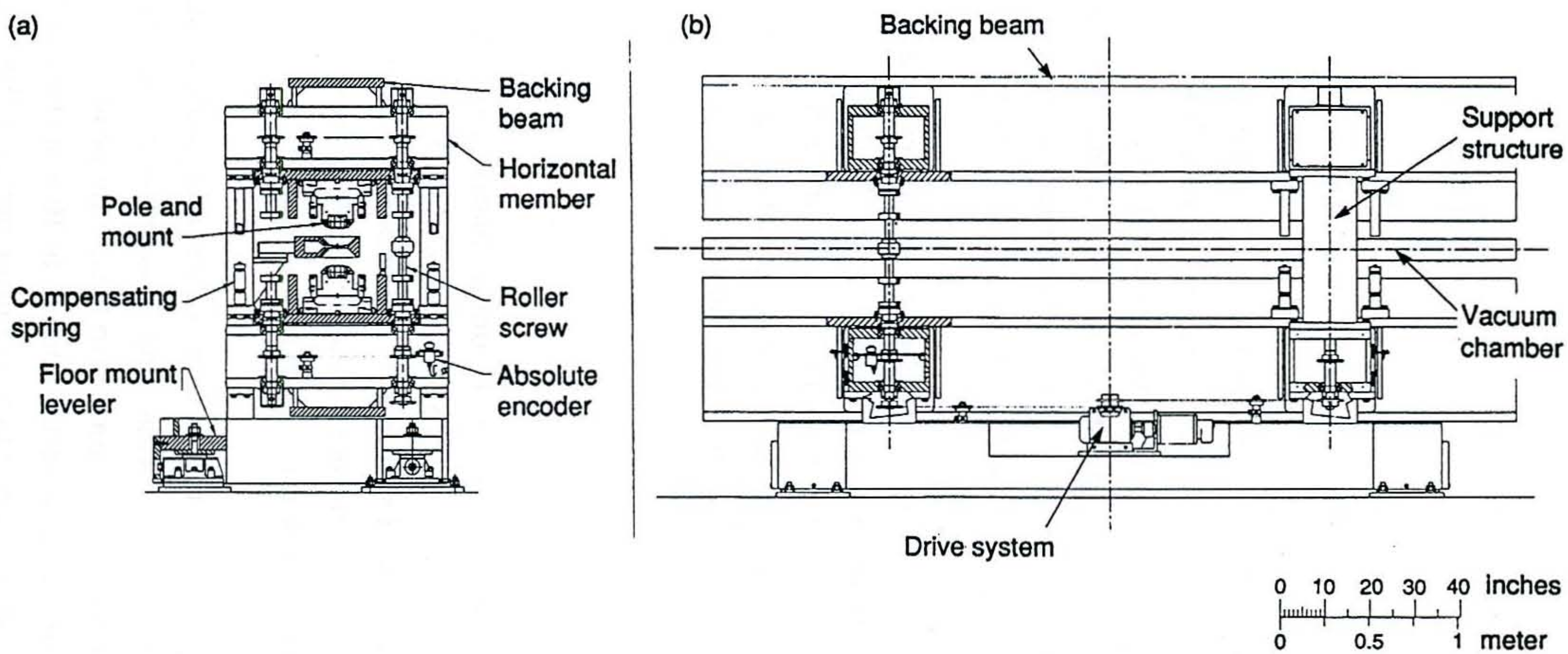


Figure 3-6. Drawing of a generic insertion device for the straight sections of the ALS storage ring showing the main structural features that all undulators and wigglers will have in common.

Major parameters and tolerances for the insertion devices were established principally by considering spectral performance goals and achievable storage-ring error tolerances.

3.3.6 Beamlines

Beamlines are the photon delivery systems that begin at the storage-ring vacuum chamber and extend through the experimental apparatus. The specific beamline topology depends upon individual beamline design specifications. Factors such as fan-width, geometric constraints of the optics, and experiment design will all influence the beamline configuration. If the beamline has sufficient angular acceptance, it might have several branchlines to accommodate multiple experimental end stations and different optical instrumentation. Each branchline might also have multiple end stations to facilitate optimum timesharing of the available beam.

From a system standpoint, the major beamline component groups consist of the front end, the branchline(s), and the end stations (which include the experimental chambers). The specifications for components which are associated with each beamline depends upon numerous factors; including the radiation source, intended end use, and design history. Beamlines for different scientific applications may differ in their design details.

Front end

The beamline front end contains the beamline instrumentation that is responsible for interfacing with the storage ring. This instrumentation is shared by all branchlines downstream from the front end (i.e., towards the experiment). The front end extends from the storage-ring vacuum chamber to the branch-line interface and functions primarily as a shutter for downstream instrumentation.

The front end consists of several vacuum valves and photon shutters inside the shielding wall that separates the storage ring from the experimental areas. Photon beam-position monitors provide information to locate the position and angle of the electron beam at the center of the insertion device to 10% of the rms beam size and divergence. A water-cooled primary photon shutter protects the beamline and personnel from synchrotron radiation when the storage ring is filled but the beamline is closed. An isolation valve immediately at the exit of the storage ring vacuum chamber is closed only when there is no stored beam in the ring (to avoid thermal damage and vacuum outgassing effects) and makes it possible to service the beam-position monitors and the photon shutter without bringing the storage ring up to atmospheric pressure.

A fast valve, a second isolation valve, and the photon shutter act together to protect the storage-ring vacuum against accidental venting of the beamline. The second isolation valve is the main means for isolating the storage-ring vacuum chamber from a beamline; it is pneumatically actuated and is locked in the closed position in case of compressed-air failure. The fast valve closes in accidental venting events only and affords temporary protection until the photon shutter and primary valve close. A personnel safety shutter is an absorber of high-energy bremsstrahlung and is closed during injection and when personnel require access to locations that have a bremsstrahlung line of sight to the storage ring. A third isolation valve just outside the shielding wall permits the isolation of the front end from the rest of the beamline.

The front end ends at the branch-line interface. The instrumentation at this location is typically a vacuum tank (spool piece) with a pump-out port containing an ion gauge and thermocouple gauge for pressure measurement.

There is nominally only one front end per beamline, although some beamlines with multiple branches may have multiple components, such as safety shutters. Figures 3-7 and 3-8 show the front-end components, which are the same for all ALS undulator beamlines.

Branch Lines

After passing through a beamline front end, synchrotron radiation typically is directed into one or more branch lines by means of deflection mirrors. The beamline branch line is responsible for conditioning (bending, focusing, dispersing, transmitting, etc.) a fraction (up to 100%) of the total fan of radiation accepted by the front end. Beamlines accepting a wide fan (such as that associated with bend-magnet radiation) are good candidates for multiple branchlines. Each branchline provides a separate set of optical components for its fraction of the total beam.

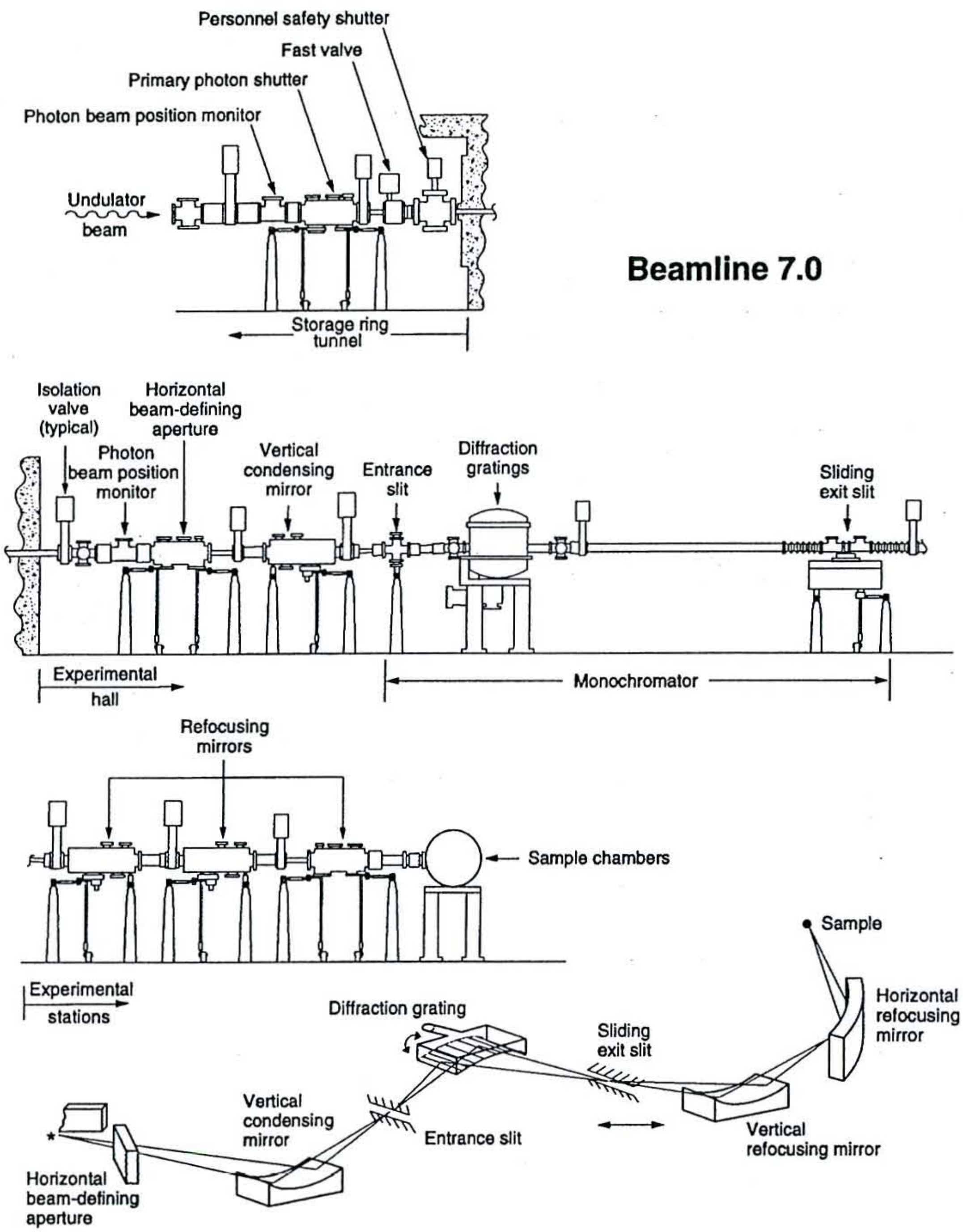


Figure 3-7. Schematic diagram of Beamline 7.0, a U5 undulator beamline. The front-end components inside the shielding wall are identical on all ALS undulator beamlines.

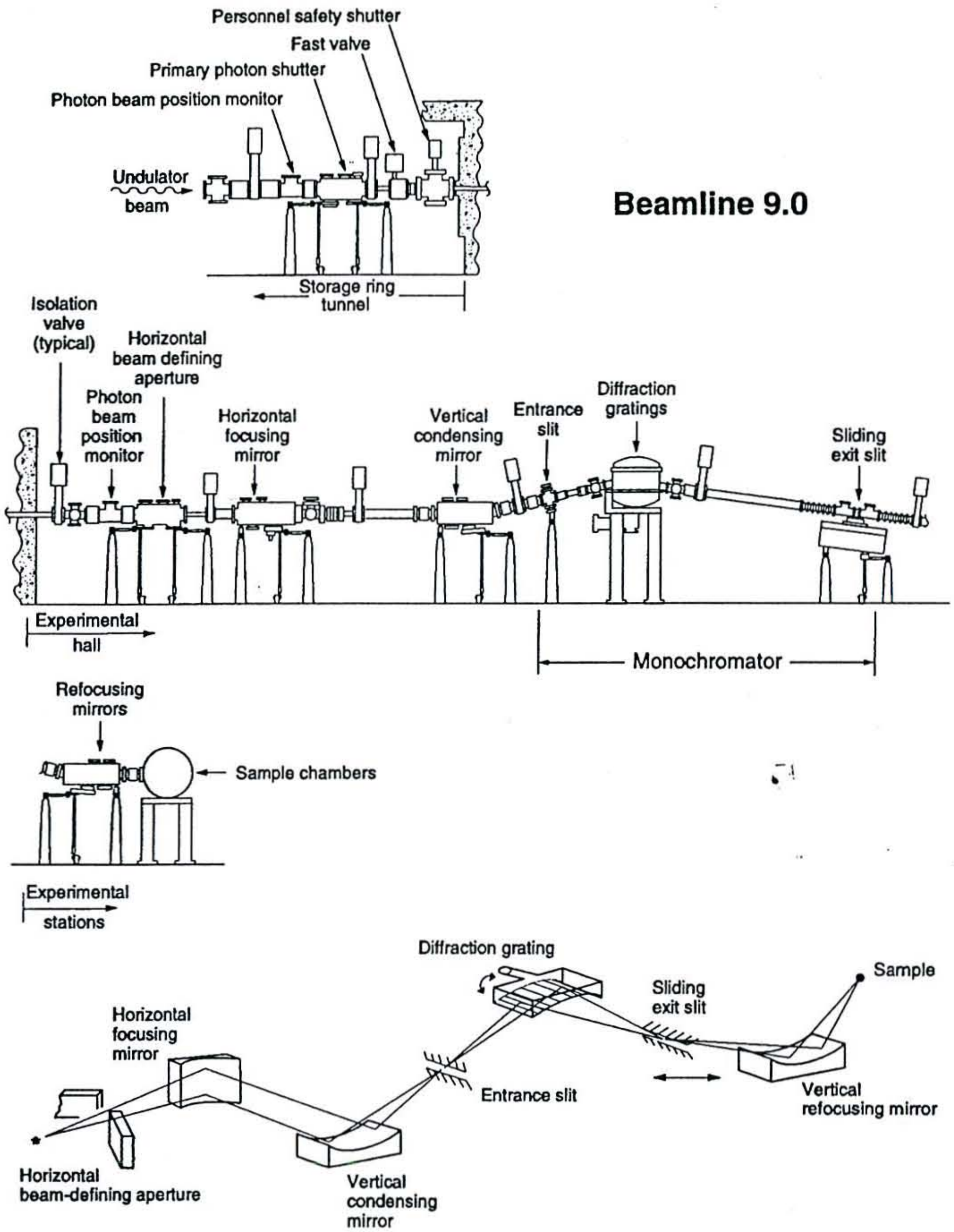


Figure 3-8. Schematic diagram of Beamline 9.0, a U8 undulator beamline. The front-end components inside the shielding wall are identical on all ALS undulator beamlines.

Branch lines may contain additional mirrors for focusing and a monochromator and/or mirrors to select that part of the spectrum required for experiments. Undulator beamlines will have beam-defining apertures located upstream of any deflection mirrors and grating monochromators. Wiggler beamlines may have crystal monochromators for higher energy x-rays. A substantial fraction of the radiation entering a beamline is absorbed by components, such as the beam-defining aperture. For this reason, some beamline components will be water-cooled.

The branch line extends from the front end to the experimental end-station. On some beamlines, the region immediately downstream of the front end may contain additional instrumentation that is shared by all branch lines. For example, a single mirror tank or aperture tank may be used to service all of the branchlines. This sharing is usually required because the branch-line beams are not widely separated until after the radiation-shield wall. The end-station is located immediately upstream of the branch line. The first component is typically the end-station personnel safety shutter; however, it might be some other upstream vacuum valve that is replicated for each end station in a multiple end station configuration.

There may be more than one branch line per beamline. A beamline vacuum system will keep the pressure at less than 5×10^{-10} Torr in the beamline.

ALS Beamlines

The ALS will be a national user facility that is open to all qualified scientists and technologists. Instrumentation of the ALS is envisaged as a community project with the primary responsibility for experimental equipment resting with the users, the responsibility for the beamlines resting jointly with the LBL and the users, and the responsibility for the insertion devices resting primarily with LBL. (However, calibration, or verification of calibration, of instruments related to the safe conduct of experiments and the safe operation of the facility, is the responsibility of LBL.)

The method of implementing this strategy is the formation of participating research teams (PRTs) consisting of investigators with related research interests from one or more institutions. Members of insertion-device teams and bend-magnet teams will receive preferential access to ALS beam time in return for their efforts. Moreover, the mix of insertion devices and their performance characteristics that is selected for development at the ALS will depend on the needs of the user community as represented by the requirements of the insertion-device teams. However, a substantial fraction of the beam time at every beamline will be available to independent investigators who are not members of the PRTs.

If branches are not counted as separate beamlines, the ALS can accommodate 10 insertion-device beamlines and 24 bend-magnet beamlines, with provisions for an additional 24 bend-magnet beamlines, if required. During the first two years of operation, up to five undulator beamlines and five bend-magnet beamlines will be brought on line, as shown in Figure 3-9 [ALS, 1992a]. Of these, at least two undulator and one bend-magnet beamlines will be constructed by the ALS project, with the remainder being the responsibility of the PRTs approved to develop the beamlines with ALS approval and oversight (see Sections 3.5 and 6.3 for review procedures).

Based on beamline design documents [Warwick, DiGennaro, and Howells, 1989a and 1989b], engineering designs for the two spherical-grating monochromator beamlines to be constructed by the ALS have been completed, one for the U5 undulator and one for the U8 undulator, and fabrication is under way. The U5.0 beamline includes a spherical grating monochromator (SGM) with three diffraction gratings, which can cover the range of photon energies between 65 and 1500 eV with minimum radiation loss and high resolution of 1 part in 10,000 or better. The U8.0 beamline includes a spherical grating monochromator (SGM) with three diffraction gratings, which can cover the range of photon energies between 20 and 300 eV with minimum radiation loss and high resolution of 1 part in 10,000 or better. Figures 3-7 and 3-8 schematically illustrate the beamline layouts. Design activity for beamlines for undulators similar to U3.9 and U8.0 are under way by insertion-device teams.

In general, bend magnet beamlines require that collecting optics be placed close to the source, inside the shield wall, to deliver radiation from a large horizontal collection angle (typically 10 mrad). The broad spectrum of bend magnet radiation from the ALS can serve experiments of various types; beamline designs vary accordingly. In most cases, however, spherical-grating-monochromator beamlines are essentially identical to insertion device beamlines with the exceptions that beam-position monitoring equipment (as described above) and water-cooling of optics are not required. To reach

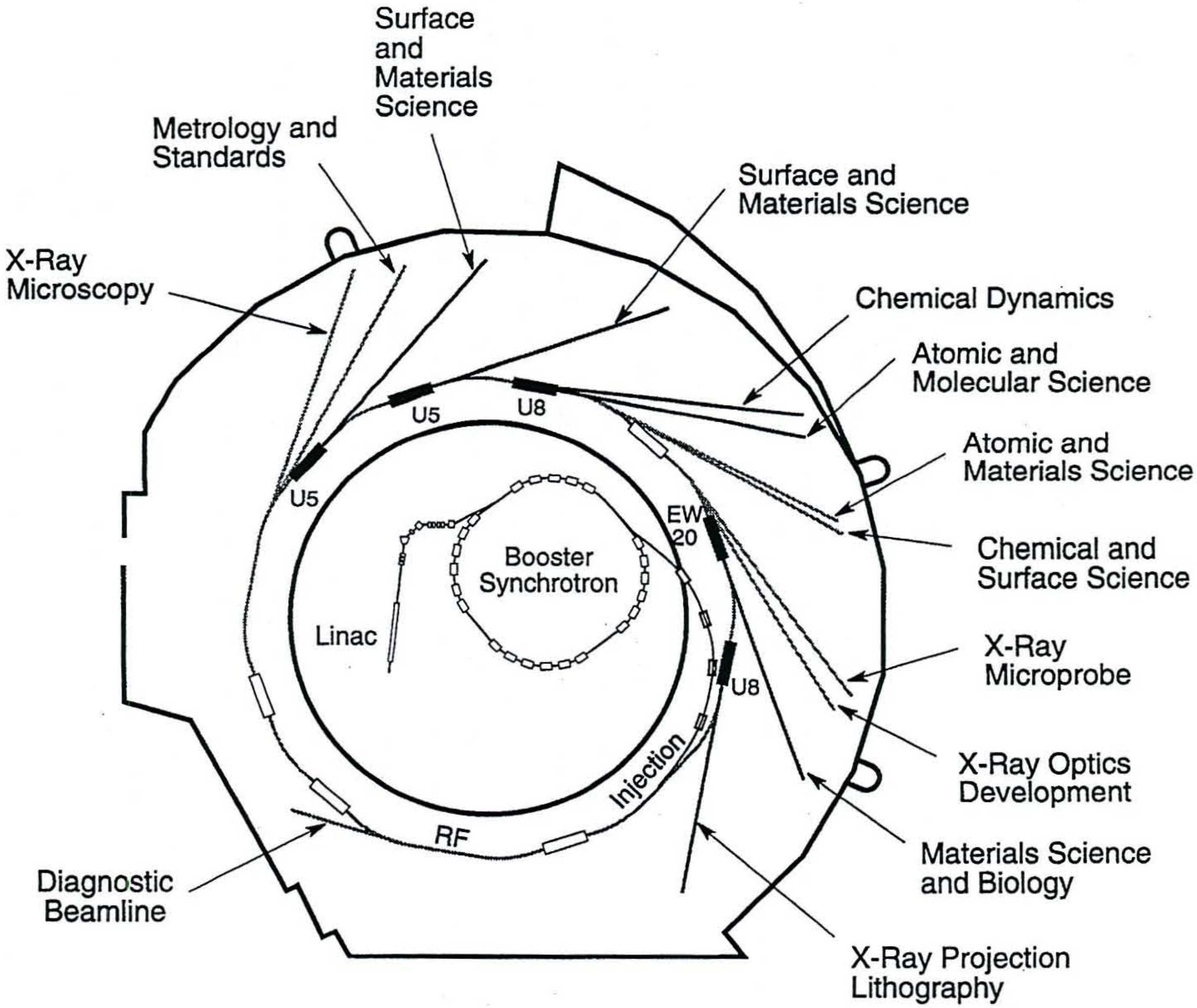


Figure 3-9. Locations of ALS beamlines planned for construction through 1995.

higher photon energies, one bend-magnet beamline will be equipped with a crystal-monochromator having a useful tuning range of 3–15 keV (defined as 10% of the flux at 10 keV) for silicon crystals.

Beam Test Facility

The beamline for the BTF is an electron-beam transport line. It comprises dipole bend magnets and quadrupole focusing magnets. There are two bends in the beamline. The first is accomplished by three bend magnets: a 22° dipole magnet to deflect the linac beam from its usual path toward the booster and into the BTF line and two 43° dipole magnets to bend the beam into a transport tube through the linac concrete shielding wall. The second bend is accomplished by two bend magnets: two 43° dipole magnets to bend the beam toward the experimental area. Quadrupole magnets in the bends maintain an achromatic beam after the bends. Additional quadrupole magnets allow a wide range of transverse beam sizes to be delivered to the experiments.

3.3.7 Experiments

The beamlines guide the synchrotron radiation to the experimental areas. The beamline end station is responsible for providing the appropriate environment for experiment support and for investigator access. The end station may comprise a relatively complex set of components, such as a beam diagnostic region, plus a personnel safety shutter, and a fully shielded and interlocked hutch for experiments that use harder x-rays, or it may comprise simply an isolation valve and the experimenter's vacuum chamber.

The end station extends from the end-station interface through the experimental apparatus. Some branch lines may have several end stations in tandem and/or in parallel.

The end station instrumentation consists primarily of the experimental apparatus. It also contains minimal instrumentation to isolate the end station from the branchline. There are diagnostic components which are used to align and qualify the upstream optical components. The instrumentation will vary depending upon the specific experiment requirements. Depending on the needs of the users, experimental areas may contain a number of manually or electrically operated vacuum isolation valves, vacuum delay lines, differential pumping stations (to permit samples to be at higher pressures than allowed in the beamlines), and radiation-transparent solid windows (to isolate the sample chamber from the beamline).

The equipment in the experimental areas will reflect the requirements and interests of both categories of users, members of PRTs and independent investigators who may use PRT experimental chambers or bring their own. Most will involve vacuum chambers with UHV capability, movable specimen stages for positioning and orientation of samples in the synchrotron-radiation beam, electron and photon detectors and spectrometers, and ancillary diagnostic instrumentation. Some areas will have cryogenic equipment. Some areas will be for the investigation of gaseous samples and will have mechanisms for introducing the sample into the chamber without degrading the UHV environment elsewhere in the beamline. Some areas may have the capability to fabricate specimens in-situ by, for example, molecular-beam epitaxy, or to subject them to structure- or behavior-changing treatments, such as changing the characteristics of a solution containing biological-cell structures. Some areas may have associated facilities nearby for sample preparation and hazardous material containment. All experimental areas will have extensive instrument-control and data-acquisition computer systems with links to the ALS computer system.

To a great degree, end stations for VUV and soft x-ray experiments with synchrotron radiation are based on a generic structure, namely, an ultrahigh-vacuum (UHV) chamber, to which numerous instruments for sample preparation, manipulation, and characterization, as well as detectors and spectrometers for electrons, photons, and ions, are appended, as required by the specific experiments to be conducted. For example, low-energy electron diffraction (LEED), reflection high-energy electron diffraction (RHEED), and scanning tunneling microscopy (STM) instruments are important for characterization of solid samples, whereas gas-phase samples require a gas-handling system in the experimental chamber, as well as a differential-pumping system to isolate the sample from the UHV environment of the beamline and the storage ring. For chemical reaction dynamics, end stations are somewhat more specialized. For example, lasers are used to create well-characterized initial conditions before the initiation of chemical reactions in chambers equipped with molecular beam sources.

For hard x-ray experiments, radiation-protection hutches are required for personnel protection, but maintenance of an ultra-high vacuum is not always needed in the sample chamber, a potential advantage for examining materials in near-natural environments. The absence of UHV vacuum chambers also makes it more practical to construct special-purpose experimental stations for specific purposes, such as a fluorescence x-ray microprobe.

Beamlines, including the experimental end stations, may be up to 35 meters in length, as measured from the radiation source (insertion device or bend magnet). The size of an experimental area will vary considerably, according to the type of research for which it is designed. Typical areas may range from 10 to 100 square meters.

There may be more than one end station per branch line.

Beam Test Facility

Two classes of experiments are planned initially for the BTF. The first is a plasma lens experiment in which plasmas are used to focus beams of relativistic electrons, a candidate technology to enhance the luminosity of future linear colliding beam accelerators; the second is an orthogonal laser-electron beam Thomson scattering experiment to investigate techniques for measuring beam sizes relevant to future linear colliders and the possibility of generating intense, femtosecond pulses of short-wavelength x-rays.

3.4 Description of Organization

3.4.1 ALS Organization

On October 1, 1992, the ALS organization shifted from that of a construction project to one more appropriate for an operating facility, thereby reflecting the actual nature of daily activity. The following paragraphs describe the position of the ALS facility within the LBL structure and the operational structure of the ALS organization.

The LBL organization (see Figure 3-10) vests primary responsibility for all activities in the Laboratory Director. Reporting to the Laboratory Director, the Associate

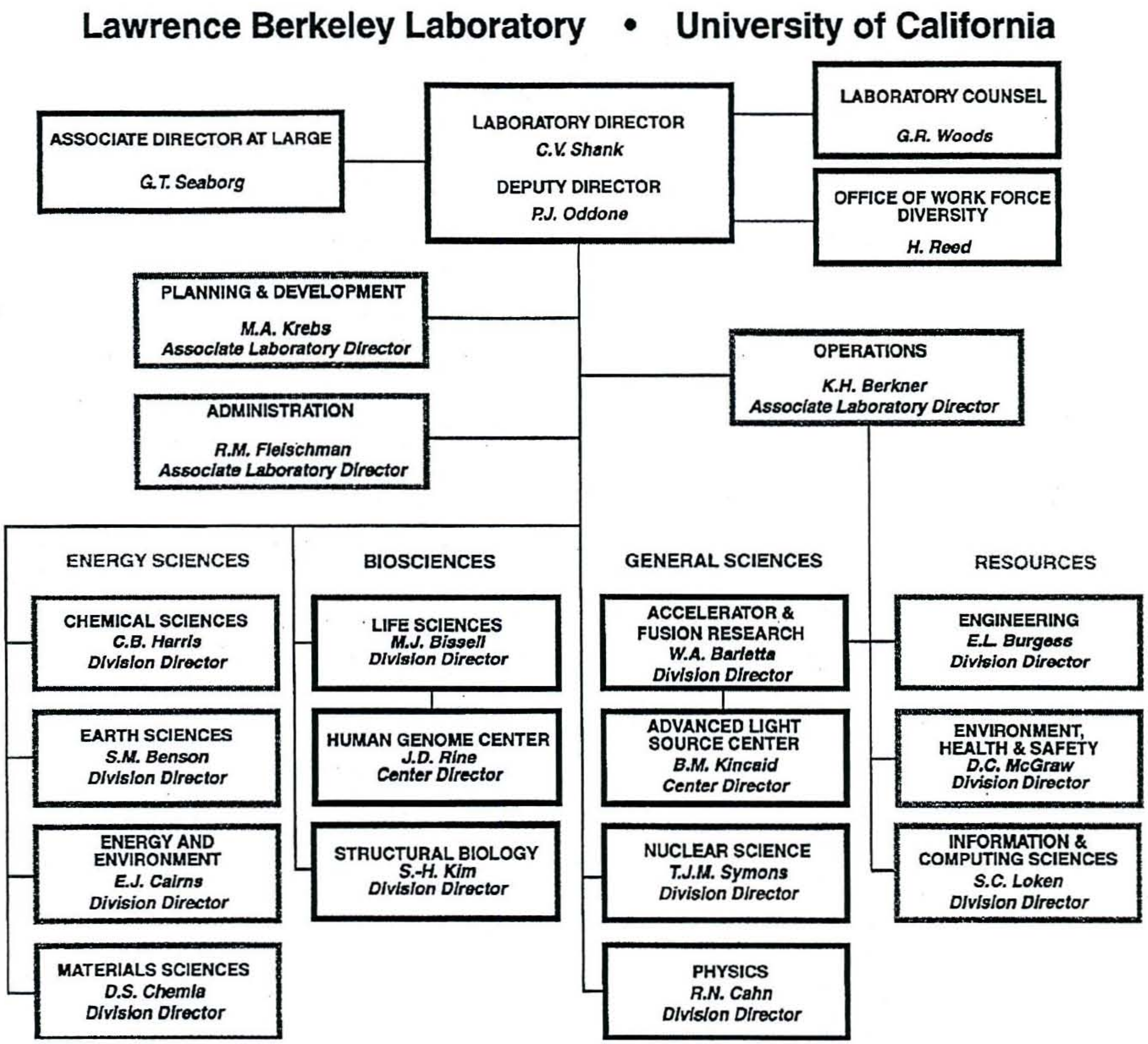


Figure 3-10. Lawrence Berkeley Laboratory organizational chart.

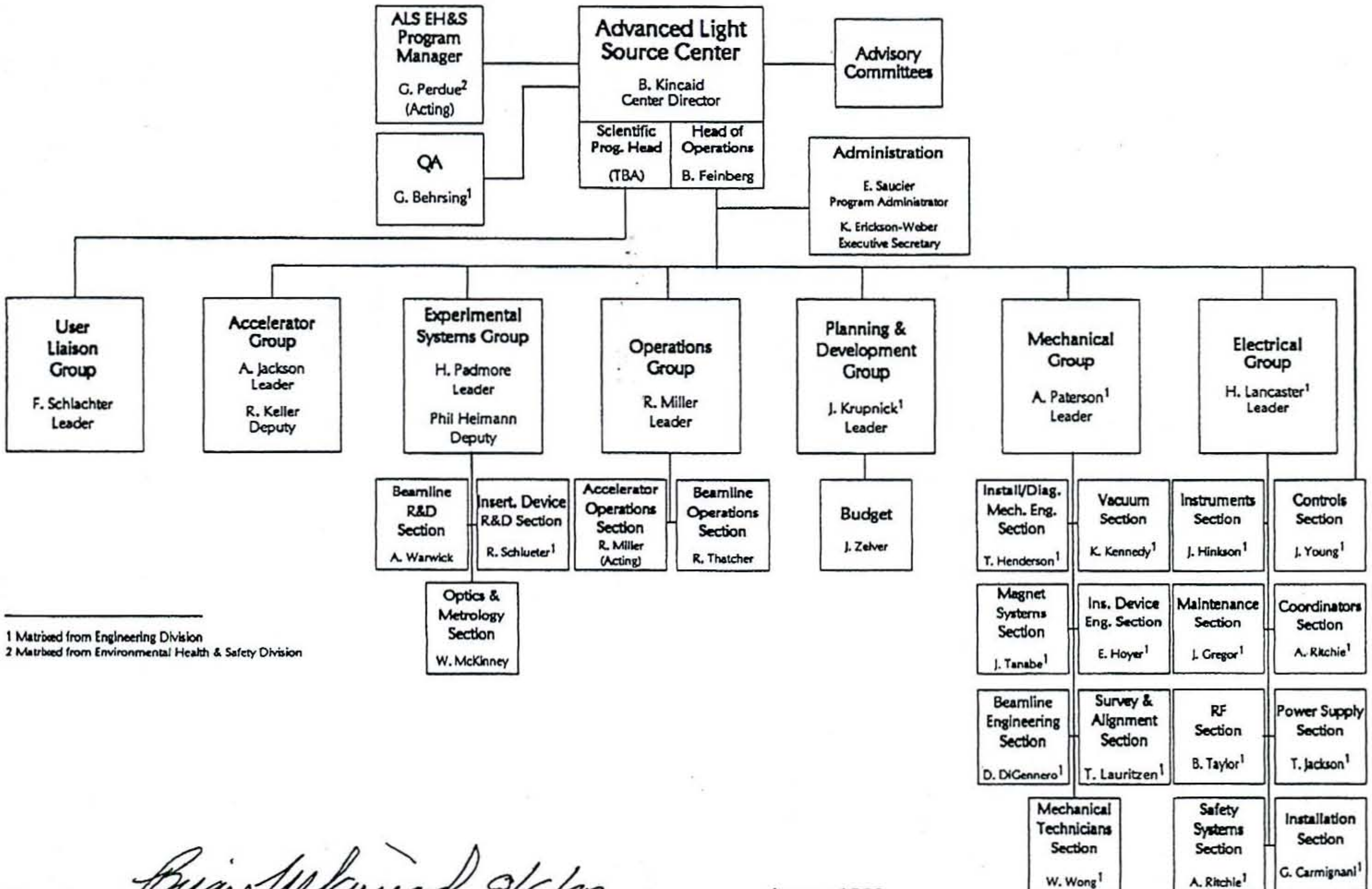
Laboratory Director for Operations has oversight over the Accelerator and Fusion Research Division (AFRD), the Engineering Division, the Environment, Health, and Safety Division (EH&S), and the Information and Computing Resources Division, each of which has a Division Director. As a construction project, the ALS was a group within AFRD. As an operating facility, the ALS has the status of an LBL Center whose home remains within AFRD.

In the new ALS organization, full responsibility for operation of the facility, and development of the scientific program resides with the ALS Center Director (see Figure 3-11). Duties of the Center Director include, evaluating the need for an applying appropriate Quality Assurance policies to all ALS activities, establishing and maintaining an active environment, safety, and health program, setting overall goals for the facility, authorizing new programmatic and major R&D activities and securing and assigning resources within the ALS organization, and development of the scientific program. As the Director of an LBL Center, the ALS Center Director has direct access to the LBL management by such means as participation in meetings of the Division Directors.

Reporting to the Center Director are the Head of Operations, the Scientific Program Head, the ALS EH&S Program Manager, and the Quality Assurance Officer.

The Head of Operations is responsible for all activities related to facility operations, for facility planning and development, and for acting as Director in the absence of the Center Director. Specific duties include providing oversight of operations, allocating resources within the organization, leading overall planning for the ALS Center, and ensuring that the operation of the ALS meets user and scientific goals. For these purposes, the ALS is divided into functional groups, the leaders of which report to the Head of Operations:

(1) The Accelerator Group is responsible for planning R&D and technical development leading to enhanced capabilities of the accelerator complex, for overseeing improvements of accelerator capabilities and operations needed to implement new capabilities, for overseeing the health physics program to ensure that accelerator improvements are appropriately monitored for radiation-field changes, and for scientific support of relevant activities in other departments.



1 Matrixed from Engineering Division
2 Matrixed from Environmental Health & Safety Division

Signature: Brian M. Kincaid 8/6/93
Date

August 1993

Figure 3-11. Advanced Light Source organizational chart

(2) The Experimental Systems Group is responsible for planning R&D and technical development leading to enhanced capabilities of the experimental facilities, for overseeing improvements and other projects needed to implement new capabilities, for safe and efficient physics support of user-related activities, and for scientific support of relevant activities in other departments.

(3) The Mechanical Group is responsible for providing engineering and technical support for R&D and improvement activities of the programmatic groups, providing maintenance of operational systems, and overseeing selected projects needed to implement new capabilities.

(4) The Electrical Group is responsible for providing engineering and technical support for R&D and improvement activities of the programmatic groups, providing maintenance of operational systems, and overseeing selected projects needed to implement new capabilities.

(5) The Operations Group is responsible for ensuring safe and efficient facility operations, ensuring safe and efficient technical user support, and for organizing and scheduling required facility maintenance.

(6) The Planning and Development Group is responsible for overseeing planning of improvement projects needed to implement new capabilities, for overseeing the planning and budget process to ensure optimum use of the budget, and for ensuring required tracking of non-operations projects.

(7) The Administration Group oversees all administrative operations, including personnel administration, budgeting, planning and scheduling, facilities management, and inventory control, and it represents the ALS in administrative contacts with external organizations.

The Scientific Program Head is responsible for the development of the scientific program, which includes promoting the unique ALS capabilities to the user community and to potential new user groups, as well as oversight over user services and administration. Specific duties include supervising the user program, chairing the

Program Review Panel, acting as scientific representative of the ALS, and ensuring that the operation of the ALS meets user and scientific goals.

The User Liaison Group Leader reports to the Scientific Program Head. The User Liaison Group plans and organizes workshops in area related to the ALS scientific programs, organizes advisory group meetings, initiates and implements procedures for users (including proposals and user EH&S), represents user concerns and needs to the ALS Center management, and ensures that priorities are communicated to operational support groups. Additional duties include writing and editing (publicity, reports, documentation, manuals, and newsletters) and user administration (site access, experimental floor access, proposal administration, accounts, publicity, meeting organization, annual report preparation, travel, housing counseling, and parking).

The EH&S Group provides technical input and evaluations as needed to support ALS activities; it carries out radiation monitoring, EH&S audits of the facility; and it develops and administers hazard communications and chemical training programs and EH&S training programs for users. Within the EH&S Group, the Safety Office Administrator provides assistance to all groups in preparation of procedures.

The Quality Assurance Officer assists in carrying out the ALS QA effort through preparation and review of the ALS Center's Project and Facility Notebooks prior to their submission for approval, provision of QA guidance to ALS personnel, arrangement of QA program orientation and training, and service as a communications link with the AFRD Quality Assurance Officer.

There are three primary ALS advisory committees:

(1) The ALS Science Policy Board (SPB) is appointed by the LBL Director to provide advice on major policy issues that bear on effective utilization of the ALS [ALS, 1988a]. The SPB serves two primary functions:

- To serve as a "visiting committee" to advise the Laboratory on policy aspects of ALS operation, development, and plans for the future; and

- To ensure that the ALS operates as a national facility whose development and utilization contribute maximally to scientific and technical productivity.

The SPB is composed of persons who are distinguished by excellence of scientific or technological accomplishment and experienced in the management of scientific organizations. Membership on the SPB is for a three-year term, renewable for no more than one term.

(2) The ALS Program Review Panel (PRP) is advisory to the LBL Director and provides, through the ALS Director, specific recommendations on the disposition of all proposals for the development and use of beamlines of all types [ALS, 1989c]. The PRP will review and evaluate proposals from Insertion-Device Teams (IDTs) and Bend-Magnet Teams (BMTs); it will review IDT and BMT performance, both during the beamline-construction phase and afterwards in the operations phase; and it will provide peer review of proposals for use of general-access time by independent investigators.

The members and chair of the PRP are appointed by the LBL Director. The ALS Director recommends nominees to the LBL Director after broad consultation with LBL management and with the synchrotron-radiation community through the ALS Users' Executive Committee. The PRP has nine members. Membership on the PRP is for a three-year term, renewable for no more than one term. The ALS Scientific Program Head serves as the chairperson of the PRP.

(3) The ALS Users' Executive Committee (UEC) is charged with conducting the day-to-day business of the ALS Users' Association (ALSUA). The purpose of the ALSUA is to provide an organized framework for the interaction between those who use the ALS for their research and the ALS management, as well as to provide a channel for communication with other synchrotron-radiation laboratories and, on suitable occasions, with federal agencies [ALS, 1988b]. The ALSUA, representing the research workers, is in a position to make known to the ALS management the needs and desires of users regarding operating policy, use of the ALS, user support, and other relevant issues of concern to those engaged in research at the facility. The ALSUA further provides a means for the ALS management to inform users with regard to current and future plans for the facility. Thorough discussion with users of current projects, as well

as plans for the future, places ALS management in a better position to evaluate the needs of users and enables users to plan more efficiently their utilization of the facility.

The members of the UEC are elected by mail ballot by the members of the ALSUA. The UEC has 11 members. Membership is for a three-year term. The UEC elects its own officers, who then also serve as the officers of the ALSUA. In partial fulfillment of its function, the ALSUA holds an annual meeting, normally in Berkeley, which serves as a general vehicle for communication between the ALS and the user community. In addition, the UEC meets as often as necessary, which has been approximately quarterly during the construction phase of the ALS, for direct communication with the ALS management. The UEC also establishes subcommittees as necessary or participates in joint committees, such as a user EH&S committee, to provide advice on specific issues of interest to the user community.

3.4.2 EH&S Organization

LBL EH&S

EH&S administration at the ALS will take place within the existing LBL EH&S structure in which all levels of management are delegated the authority necessary to implement LBL's health, safety, and emergency preparedness policies, as described in Chapter 1 of the LBL Health and Safety Manual [LBL, 1992a].

It is the policy of the Lawrence Berkeley Laboratory to provide a safe and healthful working environment for its employees, participating guests, and visitors and to prevent any harm to these individuals, the general public, or to the environment as a result of the Laboratory's activities. The Laboratory Director exercises the authority to carry out this policy and interpret the requirements for health, safety, and emergency preparedness placed upon the University of California as a consequence of its contract with the U.S. Department of Energy for the operation of the Laboratory.

The Laboratory Director is responsible for ensuring that LBL's health, safety, emergency-preparedness policies are carried out. The Director has delegated the responsibility and authority necessary to implement the health, safety, and emergency-preparedness policies of the Laboratory to appropriate members of the Laboratory management and staff. In particular, the Associate Laboratory Director for Operations has been delegated the authority to develop and administer the Laboratory's Health and Safety Program. Division Directors must ensure that facilities and operations for which they have responsibility are maintained free of life-safety hazards and that they comply with applicable health and safety requirements. The Director of the Environment, Health, and Safety Division reports to the Associate Laboratory Director for Operations. The primary functions of the Environment, Health and Safety Division are to ensure that LBL's scientific programs are carried out in compliance with the applicable orders of the DOE and with the regulations of other agencies having jurisdiction; to provide professional support in various disciplines of the Environment, Health and Safety Division to the Laboratory's scientific programs; to assist in the development of health and safety regulations; and to provide liaison with local, state, and federal agencies and with various organizations in the University of California in the field of Environment, Health, and Safety.

The LBL EH&S Review Committee (SRC) advises the LBL Director on all aspects of EH&S and EH&S policy, oversees implementation of policies, and reviews hazardous operations and Operational EH&S Procedures. Its members are appointed by, are responsible to, and serve at the pleasure of the Director of the Laboratory for renewable terms of up to five years. The experimental work at LBL often involves several areas of science and technology for which there are no published EH&S guidelines or applicable codes or regulations. Therefore, the SRC has formed several subcommittees to deal with special EH&S problems of LBL programs. The Chair of each subcommittee is a member of, and reports to, the SRC. The subcommittees consist of individuals appointed by the subcommittee Chair who have a wide variety of experience in appraising difficult technical situations that might result in EH&S hazards. There are subcommittees for biological safety, electrical safety, fire and emergency preparedness, mechanical safety, radiation safety, seismic safety, toxic substances safety, toxic gas safety, and traffic safety.

To aid supervisors and employees in establishing and maintaining a healthy and accident-free working environment, the LBL Health and Safety Manual is issued. In addition, the Environment, Health and Safety Division periodically audits all LBL activities for compliance with the applicable EH&S rules and standards and provides appropriate technical services.

AFRD and ALS EH&S Committees

Environment, health and safety committees have been established to create and maintain a high level of interest in and awareness of, EH&S among all employees at all levels, to ensure that authority for EH&S is available at all levels, and to provide an EH&S system that encourages every individual to exercise their responsibility to protect themselves, their co-workers, the Laboratory property, and the environment, as described in the Accelerator and Fusion Research Division, Advanced Light Source (ALS) Group Guidelines for Conduct of Operations [ALS, 1990b]. These committees act to eliminate threats to the environment, unsafe conditions, and workplace safety and health hazards through routine inspections, and they identify and provide training, controls, and equipment needed for these tasks. The AFRD and ALS EH&S Committees function at three levels: Division EH&S Committee, AFRD Group EH&S Committee, and Supervisor/Employee Safety Circles. For this purpose, the ALS EH&S Committee is one of the AFRD Group EH&S Committees.

Other LBL division EH&S committees relevant to the ALS include the Engineering Division Safety Committee (with subcommittees for mechanical engineering and electronic engineering), and the Administration Division Safety Committee.

The AFRD EH&S Committee is chaired by the Division Director and meets every three months, or more frequently, as determined by the Division Director. Responsibilities of the Committee include: (1) develop and recommend adoption of appropriate EH&S programs to supplement the LBL EH&S program, (2) develop and oversee implementation of an effective EH&S training program, (3) review the minutes of AFRD Group EH&S Committee meetings to encourage feedback from all levels of employees in all areas of the Division with regard to problems, ideas, and solutions related to EH&S, (4) review Division injury and illness records to identify trends and/or recurring EH&S-related problems and develop appropriate prevention measures, and (5) investigate accidents upon Division Director's request and develop recommendations in light of findings. In addition there are Adjunct Inspection Teams comprised of 30 employees who provide a staff function to Committee Chair as requested.

The ALS EH&S Committee is chaired by the ALS Director and meets every month, or more frequently, as determined by the Division Director or the ALS Director.

Responsibilities of the Committee include: (1) identify unsafe or unhealthful work practices and conditions and suggest appropriate remedies, (2) supervise quarterly inspections of selected ALS work areas, (3) review the Supervisor/Employee Safety Circles' EH&S inspection reports to encourage feedback from all levels of employees in all areas of the Division with regard to problems, ideas, and solutions related to EH&S, and (4) identify specific EH&S-related problems that seem to be recurring and develop appropriate prevention measures. The Technical Safety Subcommittee meets as directed by the EH&S Committee to consider EH&S-related matters that require specific technical expertise.

Periodic Supervisor/Employee Safety Circles, as well as routine EH&S inspections of the immediate work area, are held. The Division Director or ALS Director may periodically participate in Supervisor/Employee Safety Circles and/or inspections. Responsibilities of the supervisors involved in safety circles include: (1) conduct safety circles that will provide regularly scheduled time for supervisors and their employees to discuss potentially unsafe acts and hazards and actions can be taken to control them, (2) conduct and document periodic work area inspections to identify potentially unsafe acts and hazards and to communicate EH&S issues or information from the Division Director of the ALS Director, and (3) tag and document conditions related to EH&S concerns. This documentation will assist other employees within LBL who may be trying to correct similar conditions.

ALS EH&S Organization

The ALS Director has overall EH&S responsibility for the facility and its operations. The Director has established an ALS EH&S Policy which states that the Advanced Light Source basic EH&S policy is to ensure that all activities are planned and performed in a manner which ensures that every reasonable precaution is taken to protect the health and safety of employees and the public, and to prevent damage to property and the environment. The primary source of EH&S expertise within the ALS is the EH&S Group, which acts in accordance with applicable DOE orders and the LBL Health and Safety Manual and coordinates with the LBL Environment, Health, and Safety Division. In addition, the User Support Section retains primary responsibility for interactions with users concerning all matters, including EH&S.

As described in Section 3.4.1, the EH&S Group provides technical input and evaluations as needed to support ALS activities; it carries out EH&S audits of the facility; and it develops and administers hazard communications and chemical training programs and EH&S training programs for users. The head of the EH&S Group is the EH&S Program Manager. The EH&S Group will maintain overall EH&S surveillance of the ALS facility. EH&S surveillance responsibilities include conducting inspection and work-place review activities related to both radiological and nonradiological health protection, EH&S training of ALS operating staff and users, developing facility emergency plans, and administering programs for development of required Activity Hazard Documents (AHDs) [formerly Operational Safety Procedures (OSPs)]. In addition, the EH&S Program Manager participates in design reviews to verify that EH&S considerations have been adequately addressed and included in the final design of all ALS components and systems.

As described in Section 3.4.1, responsibility for user EH&S is divided between the User Liaison Group, the Operations Group, and the EH&S Group. The User Liaison Group is responsible for proposal review procedures and for user safety procedures. The processes for reviewing proposals are described in Sections 3.5.1, and 3.5.2. A Beamline Review Committee [ALS, 1992b] has been established to aid in the review process for new beamlines, including all EH&S-related concerns.

Within the Operations Group, the head of the Beamline Operations Section oversees the scheduling and operations of a team of Operations Coordinators. EH&S on the ALS experimental floor will be the responsibility of the ES&H Group through the Operations Coordinators. In the event that EH&S-related questions or actual hazardous situations arise, the Operations Coordinators will be the initial point of contact between the users and the ALS. Their training will allow the Coordinators to deal with EH&S issues on the spot or to refer questions elsewhere if necessary. The Operations Coordinators will report on EH&S issues to the ALS EH&S Group. Approximately five Operations Coordinators will be required for full coverage of the ALS experimental floor during operation of the ALS for 21 shifts per week.

The ALS User EH&S Committee will provide an additional vehicle for direct communication of EH&S information and concerns. With members to come from the Users' Executive Committee, the heads of the PRTs, and the ALS staff (including the

EH&S Program Manager, the head of the User Support Section, and representatives from the Experimental Systems Department), this committee is still in the formative stage.

3.5 User Administration

3.5.1 Proposal Process

All experiments at the ALS undergo a formal proposal process. In broad form, the process begins with the submission of a proposal the ALS User Support Section. In addition to the EH&S Review described in Section 6.4.4, the proposal is reviewed for technical compatibility with the ALS by the Experimental Systems Group and is reviewed for scientific merit by the Proposal Review Panel. In the case of proposals from PRTs to establish beamlines, the recommendations of the Program Review Panel and the ALS Director are forwarded to the LBL Director, who makes the final decision. In the case of proposals from independent investigators, the Program Review Panel may delegate review responsibility to sub-panels or other bodies to be defined later, and the responsibility for approval lies with the ALS Director. This process is outlined in the Program Review Panel Charter [ALS, 1989c]. Scheduling beam time for approved experiments will be the responsibility of the User Support Section through a committee to be established for the purpose. Procedures describing the proposal and the scheduling processes in detail will be contained in the ALS Users Guide, which is now in preparation and will be available to all experimenters who wish to perform experiments at the ALS. Procedures will be based on experience and practices at the National Synchrotron Light Source [NSLS, 1988a].

In addition to the proposal form, an essential part of the proposal process is submission of an Experiment Form.

3.5.2 Experiment Form

The primary tool for assuring EH&S on the experimental floor is an Experiment Form [ALS, 1992c], which addresses EH&S concerns. For each experiment at the ALS, the experimenter in charge will complete this form at the time a proposal to conduct an experiment is submitted. When several experiments are to be conducted on the same beamline, a separate form will be required for each experiment. The Experiment Form will have a lifetime of six months, after which it will either expire or will have to be updated. Final approval for an experiment will consist of a signed form posted at the beamline. No experimenter will be allowed to participate in an experiment on the ALS floor without being listed on one or more approved Experiment Forms.

The Experiment Form comprises a three-page cover form and 13 attachments (Schedules A through M). As reproduced in Figure 3-12, the first page of the cover form asks for basic administrative information about the proposed experiment and the experimenter in charge and for a brief description of the experiment, It also lists 13 classes of potential hazards (EH&S concerns), which are to be checked if they apply to the proposed experiment. The second page contains space for listing all participating experimenters. The third page contains space for additional comments by the experimenter and by the EH&S Group, together with three signature blocks for approval by the EH&S Program Manager, by the Experimental Systems Group leader, and by the Scientific Program Coordinator.

Each checked EH&S concern requires that a separate schedule be filled out. As illustrated in Figure 3-13, each schedule provides the experimenter with basic information about requirements pertaining to the hazard (e.g., training, rules for handling, protective measures) and provides space for describing the hazard (e.g., listing hazardous materials and their quantities). In some schedules the experimenter is warned that it may be necessary to generate an AHD, if none exists for the hazards covered by that schedule, before the experiment can be performed.

3.5.3 Institutional User Agreement

Before beginning research, an Institutional User Agreement [LBL, 1992b] must be executed by each User Institution sending experimenters to the ALS. Agreements are required both for members of PRTs and for individual investigators, The Institutional User Agreement is an umbrella agreement that can cover all ALS projects and all user experimenters for up to a five-year period. It covers issues, such as intellectual property rights, liability, safety and health, and payment of expenses.

ALS EXPERIMENT FORM

[Please print or type]

EXPERIMENT:

Title of Experiment:	
I.D. Number:	
Beamline:	
Expected start date of experiment:	
Date of completion of this form:	
Person completing this form:	

EXPERIMENTER IN CHARGE:

Name:	
Affiliation:	
Address:	
Phone:	
Local Address:	
Local Phone:	

BRIEF DESCRIPTION OF EXPERIMENT (PURPOSE, APPARATUS):

SAFETY CONCERNS (Check all that apply):

☐	Hazardous materials	Fill out Schedule A
☐	Biological hazards	Fill out Schedule B
☐	Laser(s)	Fill out Schedule C
☐	High-voltage power supplies	Fill out Schedule D
☐	Pressure/vacuum vessels/vacuum windows	Fill out Schedule E
☐	High-temperature ovens	Fill out Schedule F
☐	Rotating or motorized equipment	Fill out Schedule G
☐	Hoists, cranes, etc	Fill out Schedule H
☐	User-constructed equipment	Fill out Schedule I
☐	Top-heavy/unstable equipment	Fill out Schedule J
☐	Sources of noise/vibration/rfi	Fill out Schedule K
☐	Other hazards	Fill out Schedule L
☐	Ventilation requirements	Fill out Schedule M

Figure 3-12. First page of the ALS Experiment Form.

I.D. Number:

ALS EXPERIMENT FORM
[Schedule A: Hazardous Materials]

INFORMATION:

- Quantities of hazardous substances allowed in Building 6 (ALS) are limited; only small quantities under strict control and in approved containers will be allowed on the floor; storage for larger quantities will be available.
- LBL's Rules for Environmental Protection require special handling of hazardous substances (and possible training about handling) from their entry point (or acquisition) at LBL to their use and to their eventual disposal. These rules can be found in PUB-5341—the Chemical Hygiene and Safety Plan, and PUB-3092—Guidelines for Generators of Hazardous Chemical Waste at LBL, and Guidelines for Generators of Radioative and Mixed Waste at LBL. Shipment and transfer of hazardous materials will be via approved carriers. These materials will not be hand-carried onto LBL property unless such transfer is specifically permitted by regulatory requirements. For "radiation protection," see PUB-3000, Chapter 21, Section H.
- An Operational Safety Procedure (OSP) might be required.

ACTION: List all hazardous substances, including solvents, required for this experiment. Attach Material Safety Data Sheets for all materials containing hazardous ingredients.

Substance	Radio Active	Cryogenic*	Flamm.	Corrosive	Carcinogenic	Total Volume	Quantity Required on Floor

* Cryogenic systems can be potential pressure hazards. Therefore, the design of cryogenic systems must be reviewed by a qualified LBL mechanical engineer. Precautions in handling cryogenics are described in Chapter 7 of PUB-3000; additional information is found in Chapter 30.

Figure 3-13. Schedule A: Hazardous Materials from the ALS Experiment Form.

By signing the Institutional User Agreement, the institution agrees that the institution's employees are responsible for and shall take reasonable precautions in the performance of their work to protect the environment and the safety and health of employees and members of the public and shall comply with all applicable LBL EH&S regulations and requirements. The agreement also states that employees of the institution shall obtain EH&S training at the earliest possible time upon arrival at LBL and in all cases before they work unsupervised or are exposed to any special hazards. In addition, an Individual User Authorization must be executed by each experimenter participating in research at the ALS and by the institution on whose behalf the experimenter is participating. In the authorization, the experimenter agrees to participate under the terms and conditions of the Institutional User Agreement.

3.5.4 Memorandum of Understanding

For each Participating Research Team, a legally non-binding Memorandum of Understanding (MOU) between the spokesperson of the PRT and the ALS Director will be generated that covers activities that the PRT is carrying out in collaboration with ALS towards the construction and operation of an insertion-device or bend-magnet beamline, including experimental chambers. The MOU asserts that the highest priority will be given to assuring the health and safety of LBL employees and ALS users and visitors, as well as to protecting the environment. The MOU specifically assigns responsibility to the PRT spokesperson to assure that all members of the PRT are made aware of and comply with all applicable safety and health regulations of LBL, the University of California, and the DOE. This is an especially important responsibility because the MOU also assigns to the PRT responsibility to support operation of its beamline during the time that independent investigators are conducting experiments.

3.5.5 Site Access

Access to LBL by visitors, including those who come as Participating Guests for the purpose of conducting research at user facilities, such as the ALS, is governed by Section 1.07 LBL Site Access of the LBL Regulations and Procedures Manual [LBL, 1991a]. Section 1.07 is currently being revised [LBL, 1990]. In the past, visitors to LBL have had to interact with at least five different and separate administrative offices: Badge Office, Personnel Office, Medical Service or Dosimetry Office, Office of Sponsored

Research Administration, and the user facility or host division. To avoid wasted time and duplication of effort, both on the part of the visitor and LBL staff, LBL has established a Reception Center where most requirements can be satisfied in a "one-stop shopping" mode.

Any LBL employee may request site access for a prospective visitor upon approval of the employee's supervisor and/or with knowledge of the employee's Division Administrator/Director. An employee who extends an invitation to a prospective visitor becomes the LBL host for that visitor. In the case of the ALS, the "invitation" comes in the form of acceptance of a proposal to conduct research and the ALS User Liaison Group is the host.

The host advises the visitor of LBL site access policies and procedures. Specifically, the host is responsible for ensuring that the visitor is directed to the Reception Center to initiate the LBL visit and that the visitor is aware of and complies with applicable LBL EH&S policies. The Reception Center is responsible for ensuring that the visitor complies with pertinent access procedures. The visitor is responsible for compliance with scientific and administrative requirements as identified by the host and/or the Reception Center and for taking reasonable precautions in the performance of work at LBL to protect the environment and the safety and health of other personnel. Responsibility for compliance with all applicable EH&S regulations and requirements of the DOE and LBL extends from the host and host division to the visitor.

In broad form, a process consistent with the draft RPM Section 1.07 for obtaining and terminating guest status at the ALS will be as follows:

(1) Written application for approval of Participating Guest status is made to the Reception Center by the User Liaison Group. The Reception Center works with the visitor and the ALS to facilitate administrative procedures needed in advance of arrival at LBL. Typically, for example, an experimenter with an approved proposal to conduct research at the ALS would have executed an Institutional User Authorization and the experimenter's institution would have executed an Institutional User Agreement, as described in Section 3.5.3, in advance of arrival at LBL. These agreements would provide for the establishment of accounts for use of LBL computers, telephones, stores, photocopier, and shop services.

(2) The Reception Center confers approval of visitor status based on several criteria, including documented receipt of the above-mentioned contractual agreements.

(3) The Reception Center issues visitor identification in the form of a badge, card, or other means of identification, indicating the appropriate category of Participating Guest (User, Scientific Collaborator, Student, etc.), as well as a parking permit and account numbers, as applicable. Information about the visitor is entered into a database whose contents are accessible to the ALS User Liaison Group.

(4) The Reception Center issues appropriate EH&S publications to the visitor and determines training requirements in conjunction with the ALS. General training requirements that can be satisfied at the Reception Center include attendance of a new employee orientation that includes EH&S information and issuance of a personal radiation dosimeter after viewing a video presentation on radiation safety. ALS-specific training that is dependent on the anticipated need of the visitor to enter laboratories, shops, and exposure to hazardous activity will be discussed in Section 3.5.6

(5) Having completed procedures required by the Reception Center, the ALS Participating Guest proceeds to the ALS reception area in Building 6. The ALS User Liaison Group oversees all aspects of the user's stay at the facility from the initial proposal to build a beamline and/or do an experiment to the completion of the activity. The User Liaison Group will maintain user records, experimental records, and training records.

(6) At the end of a project or experiment, the ALS sends the Reception Center a notice of departure and the visitor stops at the Reception Center as part of the departure procedure to surrender any parking permit, radiation monitor, and other appropriate administrative material. In the event that no notification of departure is made, visitor status terminates automatically on the expiration date indicated on the visitor's record.

3.5.6 User Training

An ALS User Plan [Schlachter, 1992] provides the basic guidance for assurance of user EH&S. The plan has been developed in consultation with the ALS user community, principally through the ALS Users' Executive Committee and spokespersons for PRTs, beginning with an ALS User Safety Workshop that was held in November 1991. The plan has been approved by the LBL Accelerator and Fusion Research Division and the Environment, Health, and Safety Division. It was also presented to DOE at the ALS Semi-Annual Reviews.

Daily work with users on the ALS floor is the responsibility of the head of the Beamline Operations Section, who handles day-to-day user issues, such as storage, crane operation, and contact with LBL crafts. In particular, the head of the Beamline Operations Section has joint responsibility with the ALS EH&S Program Manager for access to user laboratories, chemical handling and storage areas, and vacuum assembly areas. The head of the Beamline Operations Section will also coordinate the scheduling and operation of a team of Operations Coordinators, who will be responsible for EH&S on the ALS floor. The Operations Coordinators will be the initial point of contact with users for all EH&S questions that arise on the experimental floor. User needs and accelerator operations are coordinated by means of frequent periodic meetings within the Operations Group between the heads of the Accelerator Operations Section and the Beamline Operations Section. They will discuss, among other issues, potential hazards to users that might arise from accelerator operations.

RPM Section 1.07, the Institutional User Agreement, the Individual User Authorization, and, in the case of PRTs, the Memorandum of Understanding all require that each Participating Guest who works at the ALS be responsible for his/her safety and health, which includes acting in a prudent and responsible way when dealing with hazards and seeking help when unsure of proper procedures. Each person is responsible for ensuring that his/her actions do not endanger others and for reporting unsafe conditions and activities. Users are responsible for the safe conduct of their experiments and for having the knowledge and plans necessary for dealing with hazards or potential accidents in their experimental areas.

Since the ALS is a multiple-user facility with many types of operations and experiments under way simultaneously, there are significant differences between the EH&S aspects of activities performed at the ALS and at laboratories dedicated to a single use by a small number of experimenters. In addition to the training discussed below, information about EH&S at the ALS is available from the following documents:

- the LBL Health and Safety Manual provides a comprehensive guide to EH&S issues and defines the EH&S rules at LBL.

- the ALS Beamline Design Requirements [ALS, 1993a] interprets EH&S issues as they apply to the facility and will provide ready answers for specific questions on radiation, protective interlocks, handling of cryogenic materials, handling of hazardous materials, how to respond in emergencies, such as fires or earthquakes, etc.

- Light Source Procedures and Conduct of Operations Procedures provide specific guidance for operating equipment and systems during normal and postulated abnormal and emergency conditions (see Section 6.1). Appendix 1 lists the procedures in place at the time this FSAD was prepared.

Visitor EH&S training falls into several categories: (1) general EH&S training required by LBL, (2) specific training required by LBL (e.g., hazardous waste generation, handling, and disposal), (3) general ALS EH&S training, (4) training specific to the beamline at which the Visitor will work, (5) training specific to the visitor's experiment, (6) training specific to hazards checked on the Experiment Form (see Section 3.5.2), (7) emergency training, and (8) waste handling.

The ALS EH&S Group and the Training Department of the Environment, Health, and Safety Division are responsible for establishing the need for each kind of training listed and for providing the training itself. The initial stimulus for determining what training a user will need comes from the information provided on the Experiment Forms. No experimenter will be permitted to work on the ALS floor without being listed on one or more of these forms and without having the required training. The User Liaison Group will maintain records of all user training required and accomplished.

Conduct of Operations Procedure US 02-01 User Safety Training[Jones, 1993a] delineates the applicable site-specific EH&S training, radiation-safety training, and additional EH&S training required of ALS users.

The procedure requires that all first-time ALS users view a user EH&S orientation video prepared by the ALS EH&S Group. The video is available from the LBL Reception

Center during business hours or at other times with 24-hours advance notice. The orientation will include ALS EH&S procedures, radiation hazards, protective interlock systems, hutch access (if applicable), and procedures to follow in case of emergencies (earthquakes, fires, etc.). The user must sign a form indicating completion of viewing the video.

The ALS experimental floor will initially be a controlled area. Access to the floor will be controlled by posted and locked doors [Jones, 1993b]. Users will be required to wear a radiation dosimeter issued by LBL. To obtain a dosimeter, users must take a training course offered by the LBL Environment, Health, and Safety Division. The course, EHS 450 Personal Radiation Monitoring, consists of a half-hour video covering proper use of dosimeters and biological monitoring. The video can be obtained from the LBL Reception Center during business hours or by special arrangement.

All ALS users are also required to have radiation protection training consisting of a course offered by the LBL Environment, Health, and Safety Division. The course describes radiation hazards at accelerators. Classes are scheduled as needed.

Additional training may be required based on the information obtained from the ALS Experiment Form. This training will be determined by the ALS EH&S Group with the concurrence of the LBL Environment, Health, and Safety Division. Examples of additional training are laser safety, chemical handling and disposal, and high-pressure safety.

The ALS User Plan also provides that attendance at these orientations and training course will be documented. Figures 3-14 and 3-15 show an example of a record from the current AFRD training database (see Section 6.6), which contains the type of information that will also be required for users. Training records will be maintained by the User Liaison Group. Users will also be required to certify that they have received and read the EH&S material, that they have received EH&S instruction by ALS staff, that they understand the procedures, and that they will comply with them. Ongoing user EH&S meetings to discuss EH&S programs and unresolved hazards and their associated risks will be part of the plan.

The ALS User Plan also provides that an Experiment Form must be submitted for each experiment, as discussed in Section 3.5.2. Conduct of Operations Procedure US 02-05 Experiment Summary Sheet for ALS Users [Jones, 1993c] requires that a copy of the Experiment Summary Sheet must be posted at the beamline whenever the experiment is running. The form shall be filled out and signatures obtained before experimental work begins. If AHDs are noted on the form, they must be attached, as well. If the approved form is not available, the beamline will be locked out until the omission is corrected. In addition, users must complete an EH&S check list with an Operations Coordinator before an experiment is placed on line.

AFRD SAFETY AND TRAINING DATABASE

Emp. # 207301 Name HULL, DENNIS C Room 6 110 Ext. # 5142 Mail stop 80-101 P/R 9163

Supr Emp # 980198 Supr WONG, WEYLAND Supr Ext. # 5191 Report Date 11/6/92

JOB ASSIGNMENT

CLICK IN APPLICABLE BLOCKS

AFRD Group	Employee Home Division	Status	Time	Work Group		Record Division
◉ ALS	O AFRD	◉ LBL	◉ Full	O ADMIN	◉ MT	◉ AFRD
O Bevalac	O C&M	O Contract	O Part	O E	O OPs	O C&M
O Div. Office	O EH&S	O Guest	O Summer	O EI	O OTHER	O EH&S
O ESG	◉ Engineering	O Student		O EM	O PMT	O Engineering
O HIFAR	O Other	O Retired		O MG	O SCIENTIST	O ICSD
O MFE						O Plant Engineering
O Supercon						
O User						

SAFETY ROLES

CLICK IN APPLICABLE BOXES

☐ BLDG MANAGER
☐ EMER RESPONSE TEAM
☐ SUPERVISORY RESPONSIBILITIES

HAZARD IDENTIFICATION

CLICK IN APPLICABLE BOXES

☐ ADMINISTRATIVE
☐ BIOHAZARD
☒ CHEMICAL
☐ COMPRESSED GAS, WELDING & CUTTING
☐ CONSTRUCTION
☐ CRYOGENICS
☐ ELECTRICAL
☐ FIRE
☒ HAND, POWER & MACHINE TOOLS
☒ HAZARDOUS MATERIAL & OPERATION
☒ HAZARDOUS WASTE GENERATOR
☐ LASER
☒ MATERIAL HANDLING
☒ MECHANICAL
☐ NOISE
☐ PRESSURE
☒ RADIATION
☐ RADIONUCLIDES
☐ SEALED RADIOACTIVE SOURCES
☒ SEISMIC
☒ VEHICLE OPERATION
☐ WORKING SURFACE & MEANS OF EGRESS
☐ X-RAY MACHINE OPERATION

Your signature acknowledges your input into the above hazard identification

EMPLOYEE Date

Your signature acknowledges your review of and concurrence with the above hazard identification

SUPERVISOR Date

Figure 3-14. Sample record from the AFRD Staff Training Database showing EH&S duties and job-hazard identification.

AFRD SAFETY AND TRAINING DATABASE

EMP NUMBER	NAME	GROUP	SUPERVISOR	Report Date
207301	HULL, DENNIS C	MT	WONG, WEYLAND	11/6/92

EH&S TRAINING SCHEDULING

COURSE DESCRIPTION	H	S	COMPLETE	EXPIRE	SCHED
BEV0188 BEVALAC ORIENT					
EHS0010 SAFETY ORIENTATION	R		05/19/89		
EHS0013 SUPERVISOR ORIENT					
EHS0015 VDT TRAINING					
EHS0032 BLDG MGR TRAINING					
EHS0116 FIRST AID-OSHA CERT	R				
EHS0123 CPR	R				
EHS0130 FIRE EXTING. TRNG	R		07/15/91		
EHS0211 INCID. CRANE OPS	R		04/17/90	04/16/92	
EHS0212 ADV. CRANE OPS					
EHS0213 PROF CRANE OPS					
EHS0217 EARTHQUAKE SAFETY	R				
EHS0225 FORK LIFT CERT	R		10/02/90	10/01/93	
EHS0226 FORK LIFT RECERT					
EHS0256 LOTO FOR SUPR			09/23/92		
EHS0257 LOTO BY SUPR	R				
EHS0270 ATMOS TEST F/CS ENT					
EHS0286 STRAIN&SPRAIN PREV	R				
EHS0288 BACK CARE-CURRENT					
EHS0310 HALF/FULL FACE RESP			11/01/90	11/01/91	
EHS0320 SCBA					
EHS0343 HAZ WASTE GEN TR	R				
EHS0344 WASTE ACC. AREA TR					
EHS0347 RAD/MXD WASTE GEN.	R				
EHS0360 CONF SPACE HAZ					
EHS0370 LASER SAFETY					
EHS0380 HEARING CONS. PRG					
EHS0391 HAZ COM FOR SUPV			06/26/89		
EHS0392 HAZ COM - CURRENT	R				
EHS0397 CHEM SAFTY SC OPS					
EHS0401 RAD. WORKER RETRG	R				
EHS0410 XRAY MACH SAFETY					
EHS0420 RAD SAFETY ORIENT	R		01/01/99		401
EHS0430 RADIONCULIDE TRNG					
EHS0435 RISKS OF OCCUP RAD					
EHS0438 SEAL RAD SOURCE TR					

COURSE DESCRIPTION	H	S	COMPLETE	EXPIRE	SCHED
EHS0503 PRESS SAFETY ORIENT			04/07/92		
EHS0504 INTER PRESSURE TRG					
EHS0505 HIGH PRESSURE TRG					
EHS0506 PRESS. SAFETY INSTR					
EHS0507 PRESS INSP TRNG					
EHS0508 PRESS INSP REQUAL					
EHS0509 PRESS INSTALL REQ					
EHS0510 PRESS CONSULT REQ					
EHS0511 PRESSURE TRAINING					
EHS0620 RAD PROT-ACCEL	R		08/21/90		
EHS0625 RAD MONITOR&INSTR.					
EHS0630 PERSONAL RAD MON	R		09/01/89		
EHS0730 MED/BIO WASTE					
ENS0001 EMER RESPONSE					
ENS0002 HAZMAT INSTRUCTN					
ENS0003 GAS WELDING					
ENS0004 LBL CHEM HYG PLAN					
ENS0006 POWER TOOLS					
ENS0007 POWER OP PRESSES					
ENS0008 PERS PROT EQUIP					
ENS0009 RESPIR PROT EQUIP					
ENS0010 MOTOR VEH SAFETY					
HFR0001 HIFAR SAFETY ORIENT					
OSHA001 ELECT TRAINING					
OSHA002 COMP. TRAINING					
SCN0001 SUPERCON SAFE OR					

H=TRAINING REQUIRED BY HAZARD IDENTIFICATION
S=TRAINING FOR THIS EMPLOYEE REQUIRED BY EMPLOYEE'S SUPERVISOR
TAKEN=DATA FROM LAB DATABASE
COMM=ENTRY FIELD FOR GROUPS FOR NEW DATA OR DISCREPANCIES

Figure 3-15. Sample record from the AFRD Staff Training Database showing employee training received and scheduled.

SECTION 4. SAFETY ANALYSIS—IONIZING RADIATION

The ALS safety analysis was prepared in accordance with the guidance provided in DOE Order 5481.1B, Safety Analysis and Review System [DOE, 1986a] and in DOE Order 5480.25 Safety of Accelerator Facilities [DOE, 1992], including attachments. A description of the methodology used in identifying hazards, analyzing credible accident scenarios, and assessing risks is presented in Section 4.1. Ionizing-radiation hazards are identified in Section 4.2. Hazards other than ionizing radiation are analyzed in Section 5. Sections 4.3 and 4.4 discuss the radiation shielding and radiation safety system, respectively. Section 4.5 is a summary of the safety analyses of radiation hazards. Conclusions and an assessment of the overall risk associated with ionizing radiation in ALS operations, including the Beam Test Facility (BTF), are discussed in Section 4.6.

4.1 Safety Analysis Methodology

The methodology used to perform the ALS safety analysis is shown in Figure 4-1. The hazards analysis process began with a review of proposed ALS commissioning, operations, and research activities. Information concerning operations and research at similar facilities at other laboratories was also reviewed. Using the information obtained, a hazard analysis of proposed ALS activities was prepared. Potential hazards associated with the use of radiation sources were studied.

Credible hazards with potential on-site or off-site consequences were then analyzed to assess associated risk. The analyses were based on a bounding event approach, where the most severe of each particular category of credible accident was analyzed to obtain worst-case results. Each event analysis included determining the initiating occurrence, possible detection methods, the safety features that might have prevented or mitigated the event, the possible consequences, and the probability of the event occurring.

The probability estimates were made by the Technical Safety Subcommittee of the ALS EH&S Committee on the basis of the best professional judgment of the members of the subcommittee. The judgments were supported by statistics on occurrences at DOE

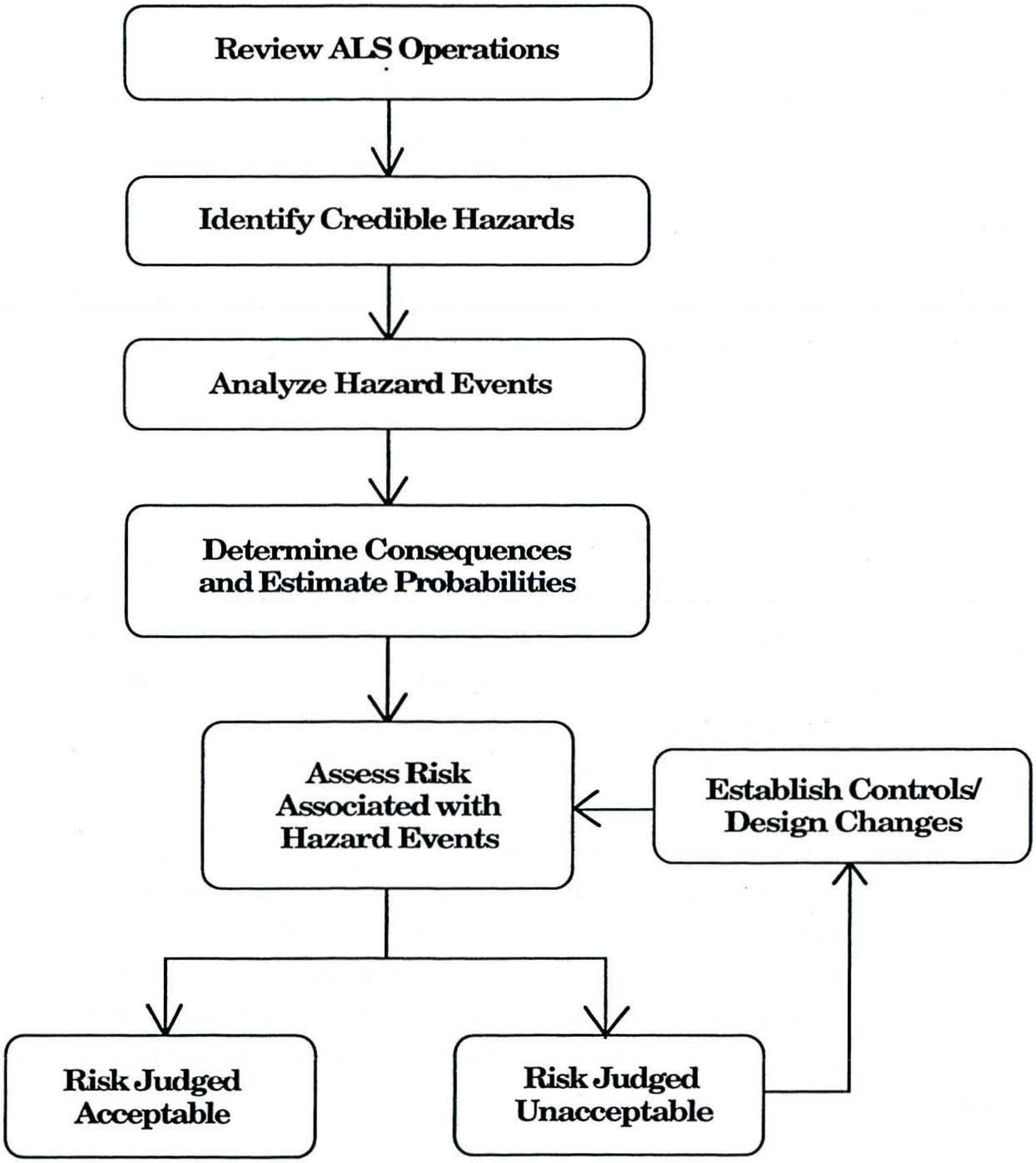


Figure 4-1. ALS Safety Methodology.

accelerator facilities for the period September 1990 to December 1992 obtained through the DOE Occurrence Reporting and Processing System (ORPS) [DOE, 1993] and by data accumulated on actual instances of exposure to radiation at LBL over the period 1981-1986 [EH&S, 1987]. In addition, site-specific design criteria for earthquakes were used in determining the probability of these events [UCRL, 1989].

Using the guidance provided in SAN Management Directive 5481.1A [SF, 1989] for conducting safety analyses, the consequences and probability of each hazard were rated by levels. The overall risk associated with each specific hazard, and then for the facility as a whole, was determined using these rating levels and the risk matrix provided in SAN MD 5481.1A.

4.2 Ionizing Radiation Hazards

The general procedures to be followed for radiation safety are defined in Chapter 21 Radiation Safety of the LBL Health and Safety Manual [LBL, 1992a], the LBL Radiological Control Manual [LBL, 1993a], DOE Order 5480.11 Radiation Protection for Occupational Workers [DOE, 1988a], DOE Order 5400.5 Radiation Protection of the Public and the Environment [DOE, 1990a], DOE Order 6430.1 General Design Criteria [DOE, 1987a], Radiological Safety in the Design and Operation of Particle Accelerators [ANSI, 1978], National Council on Radiation Protection and Measurements Report No 88 [NCRP, 1986], and California Radiation Control Regulations [CAC, 1980]. There is also an active LBL program in support of the ALARA philosophy [EH&S, 1987, LBL, 1992, LBL, 1993a].

Ionizing-radiation hazards at the ALS are due to loss of electrons at various stages of the beam acceleration and storage process and to the synchrotron radiation emerging from the insertion devices and bend magnets in the storage ring. Ionizing radiation is also produced by accelerator-related equipment, such as the klystrons that generate rf power.

Credible hazards fall into two primary categories. The first category is exposure to ionizing radiation resulting from operation of the machine. Exposures can result from normal operation of the accelerators or from accidental loss of beam. Exposures of either type are limited by shielding in the accelerator, beamline, and experimental areas and by exclusion areas in the beamline and experimental areas. Administrative procedures, including Activity Hazard Documents (AHDs) [formerly Operational Safety Procedures (OSPs)], Conduct of Operations Procedures (COPs), and Light Source Procedures (LSPs) covering personnel training, testing, radiation monitoring, and record keeping, are also used to limit exposure to radiation (see Sections 6.1 and 6.2.5). The second category is exposure of personnel inside the accelerator shielding or exclusion areas. Exposures of this type are limited by a combination of means, including interlock systems, personnel training, and administrative procedures, such as search and secure. In addition, the ALS Safety Department has assigned a health physicist to monitor operations and radiation levels and to ensure system integrity.

The following sections describe and analyze the safety systems for ionizing-radiation hazards. Section 4.3 analyzes the production of bremsstrahlung and neutron radiation and the shielding required to protect against it. Hazards due to radiation exposure will be different for those working in the ALS facility and those outside the building in the general area; hazards are analyzed for both types of personnel. The protective interlock (radiation safety) system that shuts down radiation-producing systems when an interlock chain is broken is described and its operation analyzed in Section 4.4. Administrative procedures are referred to where appropriate. Section 4.5 summarizes the analysis in the framework of the methodology outlined in Section 4.1.

4.3 Shielding for Bremsstrahlung and Neutron Radiation

In order to ensure minimum risk to the general public and to facility personnel from operation of the ALS, it is LBL policy to implement the Department of Energy regulatory radiation-safety limits, as currently expressed in DOE Orders 5480.11 and 5400.5. Accordingly, the radiation shielding design is based on the dual design goals of limiting the radiation exposure to the general public to less than 10 mrem/year (0.1 mSv/year) and limiting occupational exposure to laboratory workers to less than 250 mrem/2000-hour worker year (2.5 mSv/year) and to 1 rem/9000-hour worker year (10 mSv/year). The design goal for continuous occupancy is 0.5 mrem/hour (5 μSv/hour). These goals meet the DOE radiation-dose limit to the general public of 10 mrem/year [DOE, 1990a] and are far below the maximum allowable occupational dose limit of 5 rem/year [DOE, 1988a].

The ALS shielding configuration required to meet these design goals evolved, as described in the following sections. In brief, a basic concrete shielding design was developed. The design was based on conservative assumptions about accelerator operations and about beam losses, which were estimated from experience at other accelerator facilities. Additional calculations that were used to analyze specific shielding issues, such as the storage-ring ratchet wall, led to detailed designs. In accordance with the process adopted for approval of ALS project technical designs [Paterson and Lancaster, 1987], reviews were held to analyze the proposed shielding design, with pertinent recommendations from the reviews being incorporated into the final design. The shielding design for the injector complex (and by implication for the storage ring, as well) has been validated by radiation monitoring and personal dosimetry during commissioning in 1992. Monitoring data has shown that beam losses are lower than expected. In addition, commissioning experience with the injector has shown that some assumptions about accelerator operations are more conservative than necessary. In sum, the ALS shielding is properly designed to limit occupational exposure to ALS staff and visiting scientists, as well as to the general public at the site boundary, under both normal and abnormal operating conditions.

4.3.1 Generation of Ionizing Radiation

For synchrotron-radiation facilities, bremsstrahlung (photons) and neutrons are the dominant ionizing radiation. Electrons lost from the accelerator beam generate bremsstrahlung when colliding with residual gas molecules in the accelerator vacuum chambers, with the chamber walls, or with other objects. Neutrons are generated, primarily by the giant photo-nuclear resonance, when the bremsstrahlung is absorbed by shielding.

Different levels of photon and neutron radiation are produced during different stages of operation. For example, in the case of the storage ring, the first stage of interest is the injection cycle. The efficiency of the injection process determines the average level of radiation. However, mis-steering the beam into the storage-ring or booster-to-storage ring transfer line will produce the most significant levels of radiation, so that special consideration must be applied in designing the shielding for the injection region. The next stage of operation after injection is stored beam in the storage ring.

Under normal conditions when beam is gradually lost over several hours, one would be concerned with the radiation produced by the interaction of electrons with atoms distributed in the storage-ring vacuum chamber (gas bremsstrahlung) and the radiation produced by the collision of electrons that are slowly lost from stable orbit with the vacuum chamber. Under accident conditions, one must evaluate the radiation produced when the entire electron beam is lost at a single point in the storage ring. The final stage of operation is dumping the electron beam when it has decayed and needs to be replenished. Similar scenarios exist for the booster synchrotron and the linear accelerator.

In general, shielding consists of concrete supplemented with lead and polyethylene. As a hydrogenous material, concrete is an effective material for neutron shielding. Polyethylene, another hydrogenous material, is used to provide additional neutron shielding. Concrete also protects against bremsstrahlung, but the required thickness is so large that it is not always practical to rely exclusively on concrete. Lead, which is a more effective bremsstrahlung shield material than concrete, is therefore used to provide additional protection.

The bremsstrahlung dose equivalent far exceeds the average neutron dose equivalent and will dominate the shielding [Swanson, 1985]. Hence, it is very probable that an adequate shield for bremsstrahlung would be more than adequate for neutrons, if concrete were used. However, if bremsstrahlung were shielded primarily by non-hydrogenous materials, such as lead or iron, the neutrons may not be adequately attenuated. The combination of concrete and lead is optimized to provide maximum shielding. Additional lead and polyethylene are used for local shielding in critical locations where space or geometrical constraints are an important consideration.

4.3.2 Conservative Initial Assumptions

The design values of the occupational and site-boundary exposures determined the thicknesses of the concrete shielding around the linear accelerator and linac-to-booster transfer line, the booster synchrotron, the booster-to-storage ring transfer line, and the storage ring for protection against both bremsstrahlung and neutrons [McCaslin, 1986; ALS, 1986; Swanson, 1987]. To protect against worst-case radiation exposures, pessimistic assumptions were made concerning the accelerator operating parameters and schedule. In addition, estimates of the number of electrons that would be lost from the beam during commissioning and during routine operation under these pessimistic assumptions were made based on experience at other accelerator facilities.

The conservative assumptions about accelerator operations include:

- The injection system would have to operate at 4 Hz, rather than the nominal 1 Hz, to fill the storage ring. This is the maximum frequency at which the injection system could be made to operate without major modifications to the hardware. However, the 4-Hz option would require a major upgrade of the magnet power-supply system.

- Injection would be carried out twice per eight-hour shift, rather than once. Depending on the lifetime of the beam when operations begin, this assumption may not be unrealistic.

- Injection would be to an accumulated current of 800 mA, rather than the nominal 400 mA.

- The ALS would be operational for 1095 eight-hour shifts per year. Present planning is for operations to take place three shifts per day, five days per week, 50 weeks per year, for a total of 750 eight-hour shifts per year.

- Losses from the storage ring would occur at the maximum possible energy of 1.9 GeV, rather than the nominal 1.5 GeV at which the storage ring will operate most of the time.

- The injection system would be routinely "tuned-up" prior to an injection period. This operation was envisaged as one hour at one-fourth of the maximum intensity, followed by 15 minutes at full intensity. Experience has shown, however, that the injector complex can be brought into operation in five to 15 minutes.

Radiation hazards in the accelerator system result from capture losses in the linac, the booster, and the storage ring, from normal loss of the stored electron beam between fills, and from beam losses due to equipment malfunctions. The electron losses during injection repeat at the cycle rate of the system. Based on beam losses common at similar accelerator facilities, normal operational losses for each acceleration cycle were estimated to occur at the following places for a linac beam current of 8×10^{10} electrons per cycle:

- 4×10^{10} electrons per cycle are lost at the collimator in the linac-to-booster transfer line at 50 MeV.
- 0.8×10^{10} electrons per cycle are lost in the collimator and at the injection septum magnet at the booster at 50 MeV.
- 0.6×10^{10} electrons per cycle are lost around the booster at an average energy of less than 150 MeV during acceleration.
- 0.325×10^{10} electrons per cycle are recirculated and lost around the booster at 1.5 GeV after acceleration and extraction.
- 0.325×10^{10} electrons are lost per cycle in the booster-to-storage ring transfer line at an energy of 1.5 GeV.
- 0.325×10^{10} electrons are lost per cycle at the storage-ring injection point.
- 0.325×10^{10} electrons per cycle are lost around the storage-ring during injection at 1.5 GeV.
- The 3.3×10^{12} stored electrons per fill are eventually lost at 1.9 GeV.

4.3.3 Shielding Design

By means of empirical formulae, radiation exposures were calculated as a function of concrete thickness for these operating scenarios and estimated beam losses [McCaslin, 1986. These calculations took into account the contributions of both uniform losses during normal operation and point losses during machine malfunctions. Shielding thicknesses were then found such that the general-public and laboratory-worker dose equivalents were acceptable. Figure 4-2 shows the design values for radiation exposure at various locations around the ALS for both uniform and point losses during machine malfunctions. Figures 4-3 and 4-4 show representative results for the booster synchrotron and the storage ring, respectively, and illustrate how the shielding thicknesses required to meet the design exposure specifications were determined. In all cases, the radiation shielding has been designed to be at least as thick as the minimum calculated requirements. Even with these safety factors, radiation monitoring constitutes an ongoing activity at the ALS, with extra shielding being employed where it is deemed necessary.

The ALS radiation shielding enclosures are constructed using both cast-in-place concrete structures and precast (removable) roof panels and wall blocks. Linac-vault walls are a minimum of 4 feet thick, as is the roof. Booster-synchrotron shielding is cast in place; the tunnel walls are a minimum of 2.5 feet thick; the roof is also 2.5 feet thick. Removable roof blocks are provided in three locations around the booster for access to equipment and for maintenance. The storage ring has a fixed (cast-in-place) inner wall and a removable (precast) outer wall section and roof section around its entire circumference to facilitate beamline egress from the tunnel. Storage-ring tunnel walls are nominally 1.5 feet thick; the roof is 1 foot thick. Figures 4-5, 4-6, 4-7, and 4-8 diagram the ALS shielding configuration for the ALS accelerators. In some locations, the storage-ring shield-wall and -roof thicknesses differ from the nominal values, and in some locations lead shielding is added (see Section 4.3.4).

To verify the performance of the ALS shielding, the Oak Ridge National Laboratory code MORSE was used to calculate the neutron dose equivalents in the facility and at the site boundary [Sun, 1989, 1991]. Use of the code required the construction of a geometrical model of the ALS facility that lends itself to numerical analysis on a computer. The model generated used circular approximations of the polygonal accelerators and included representative materials for the parts of the model. The code accounts for both direct neutrons penetrating the shielding and for "skyshine" neutrons scattered in the air [Swanson, 1988]. Additional contributions from intermediate- and high-energy neutrons were added as fixed percentages (25% and 2.5%, respectively) of that calculated with the code.

Output from MORSE gives the neutron dose equivalent as a function of position coordinates. Analysis of the output showed that two representative positions adequately

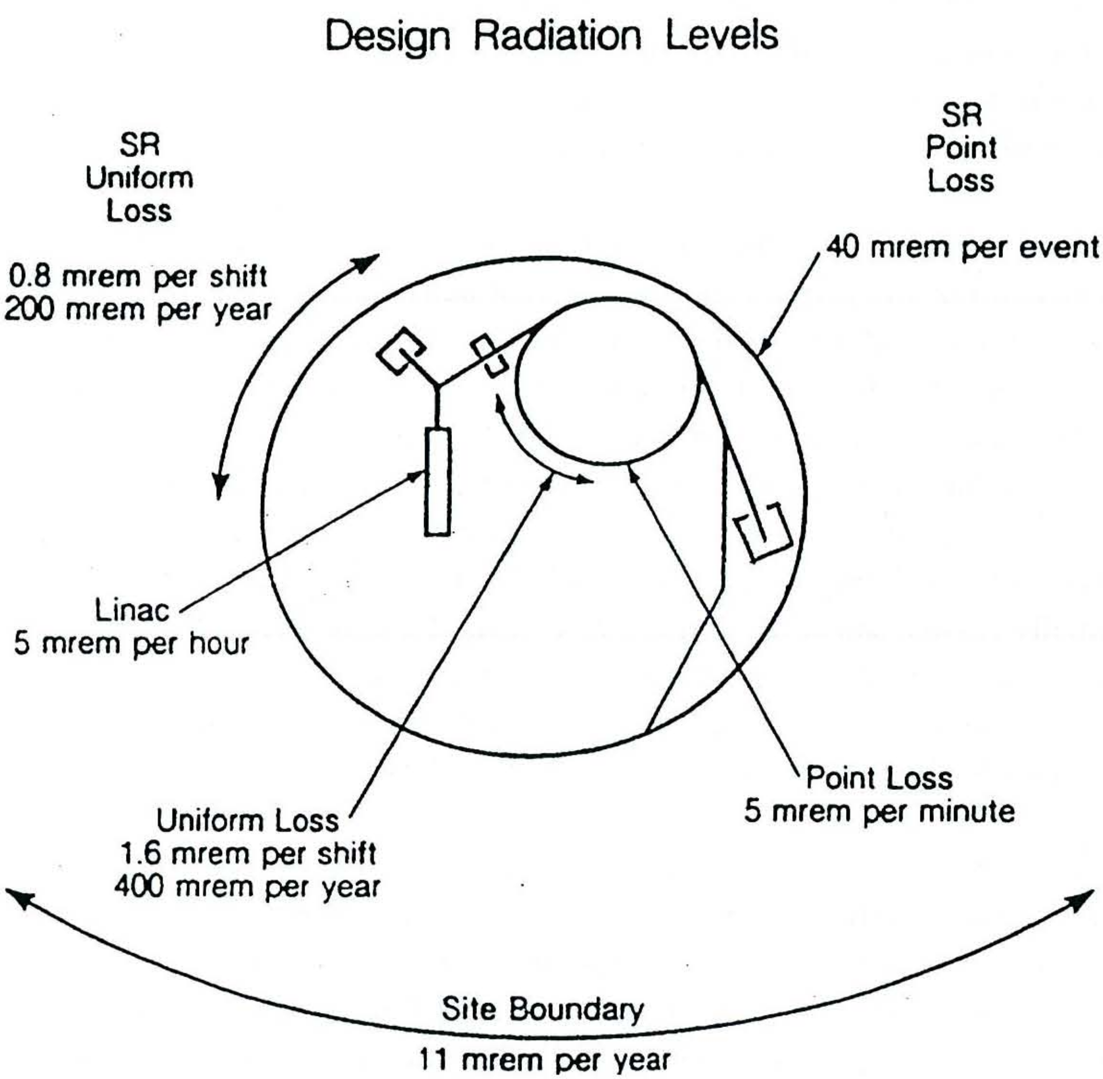


Figure 4-2. Schematic diagram the ALS accelerator area showing the design radiation levels for uniform and point losses at the storage ring, booster synchrotron, linear accelerator, and the LBL site boundary.

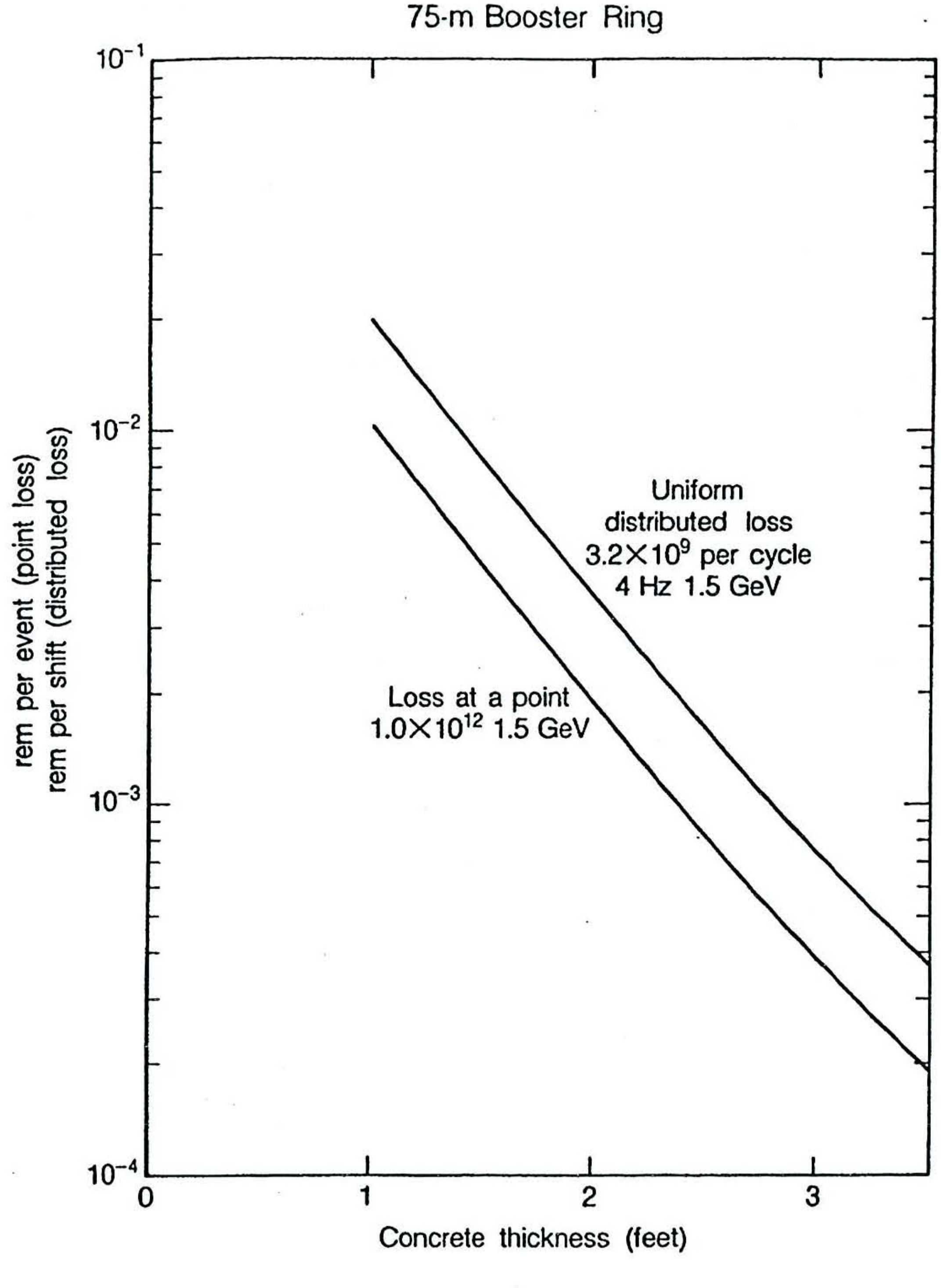


Figure 4-3. ALS booster-synchrotron occupational dose equivalent.

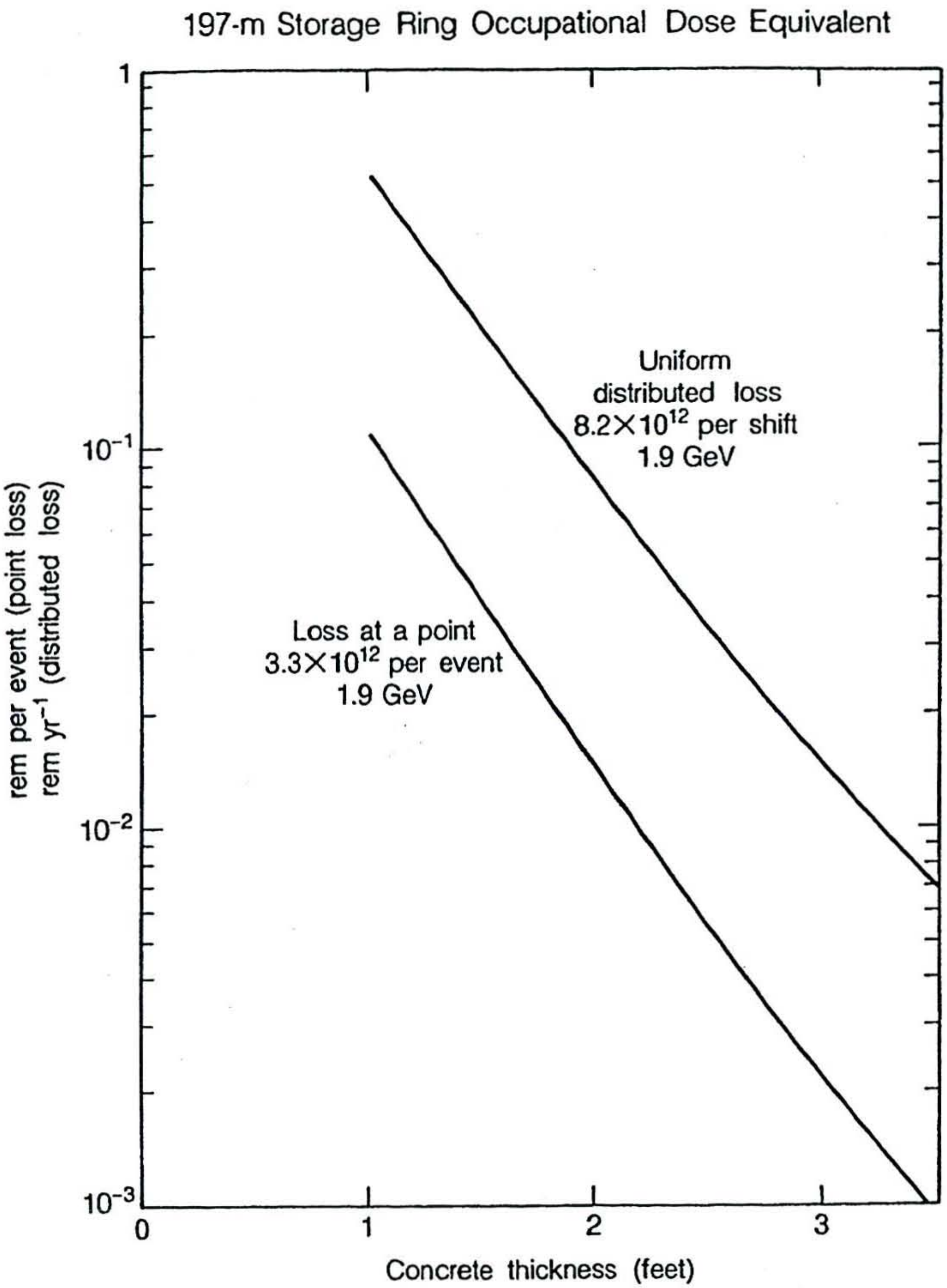


Figure 4-4. ALS storage-ring occupational dose equivalent.

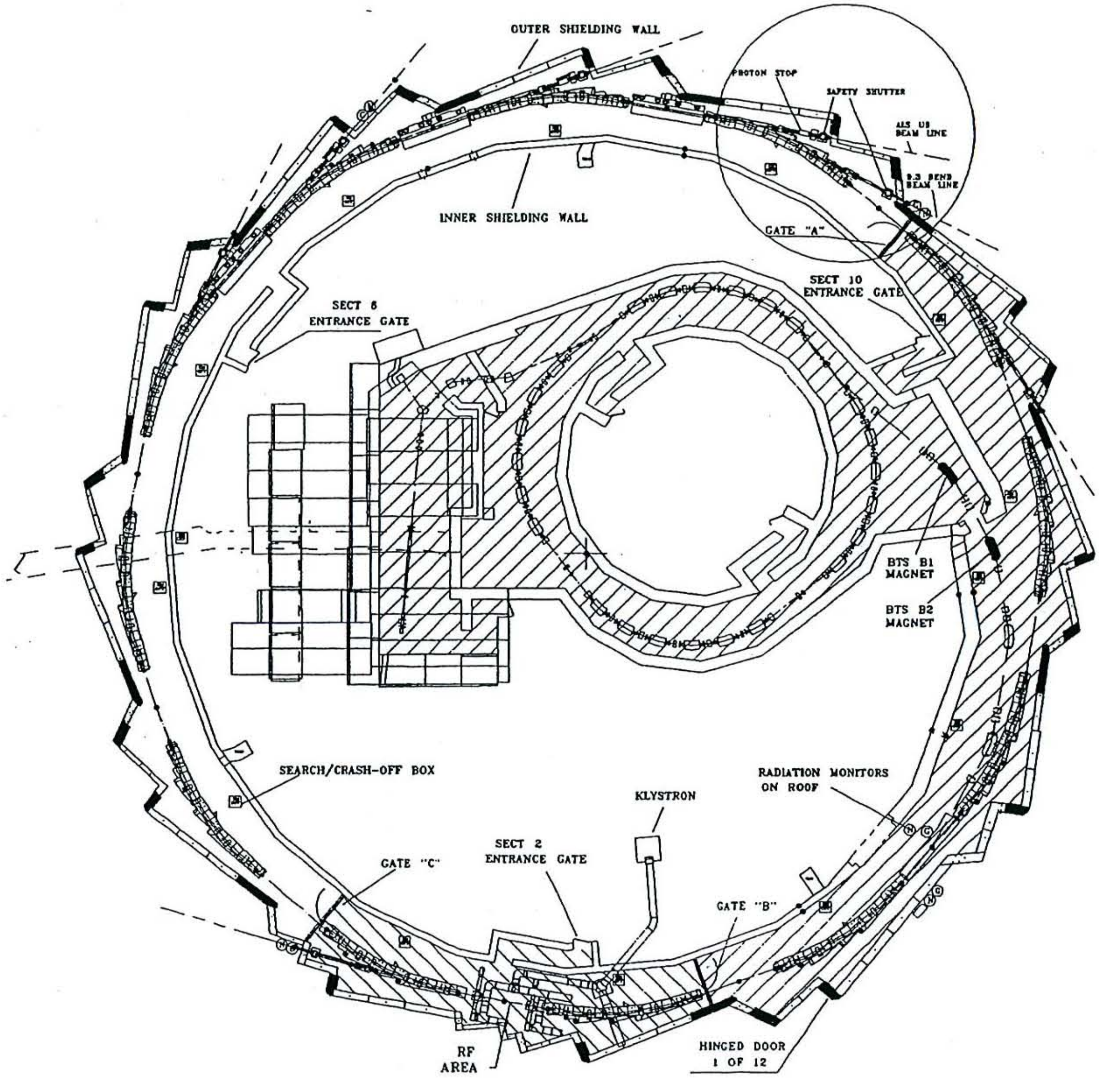


Figure 4-5. Schematic diagram of the ALS accelerator area showing the radiation shielding for the storage ring, booster synchrotron, and linear accelerator and the locations of the neutron and photon detectors.

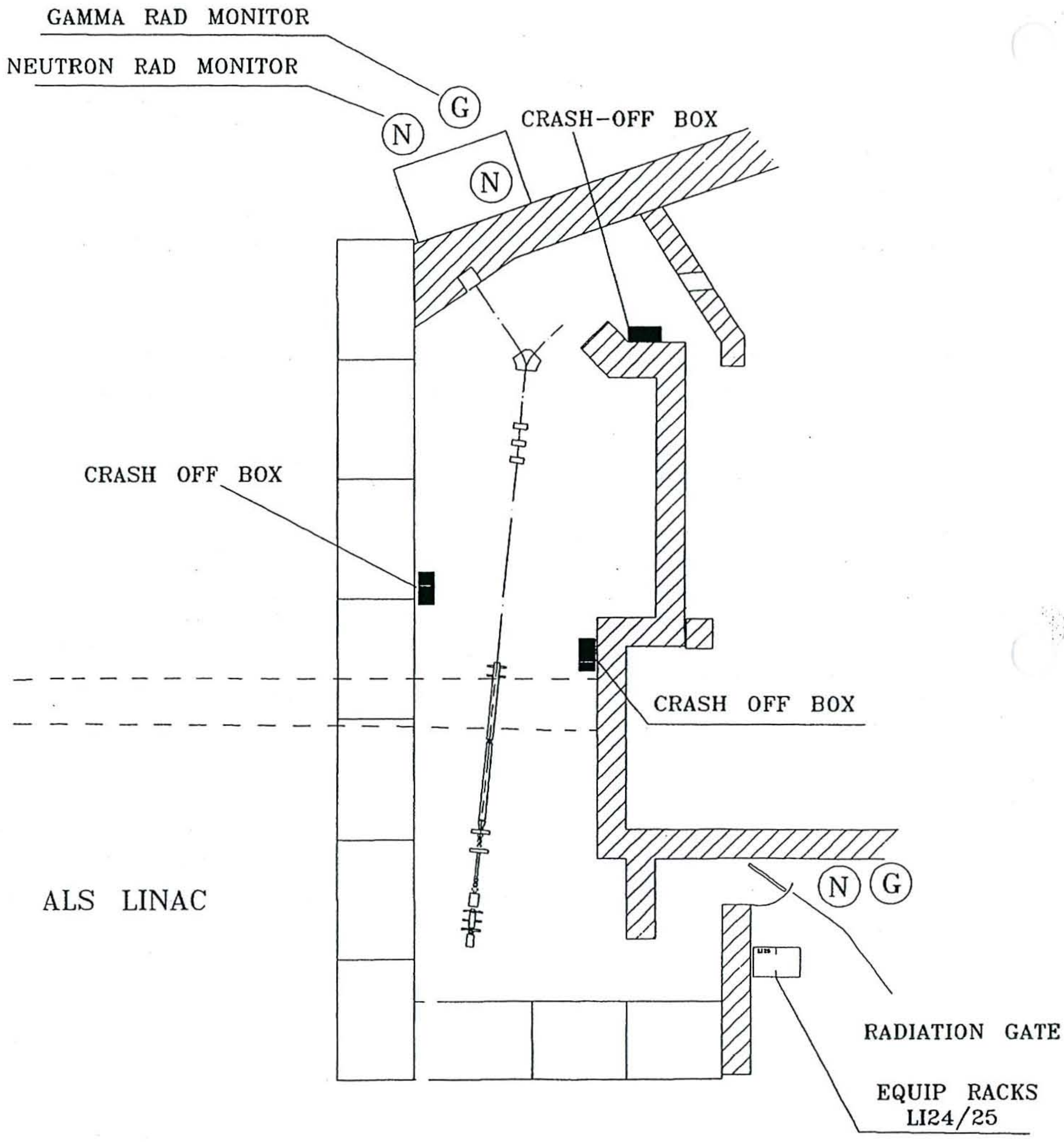


Figure 4-6. Detailed schematic diagram of the ALS linac area showing the radiation shielding and the locations of the radiation gate, the crash-off boxes, and the neutron (N) and photon (G) detectors.

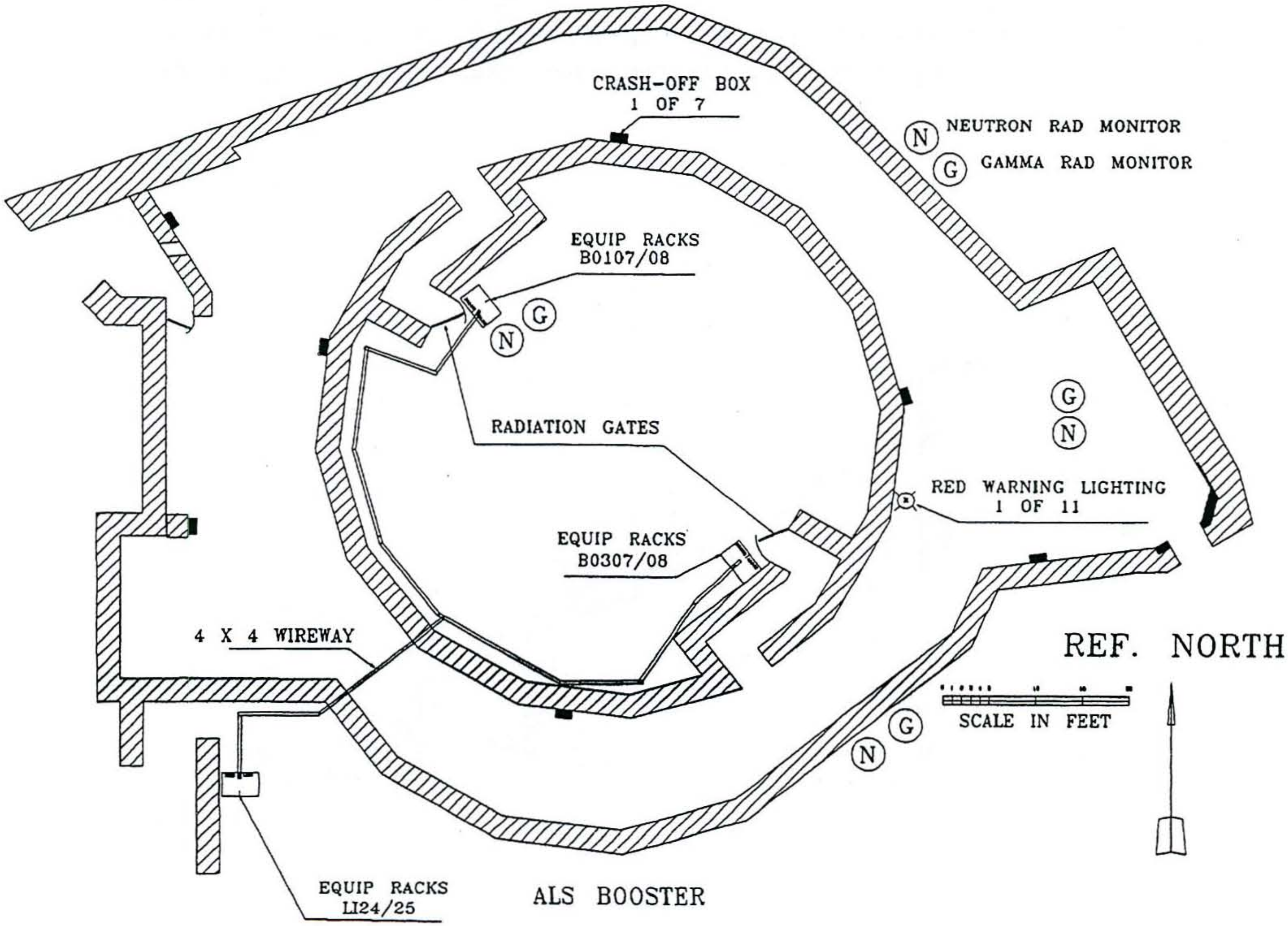


Figure 4-7. Detailed schematic diagram of the ALS booster-synchrotron area showing the radiation shielding and the locations of the radiation gates, the crash-off boxes, and the neutron (N) and photon (G) detectors.

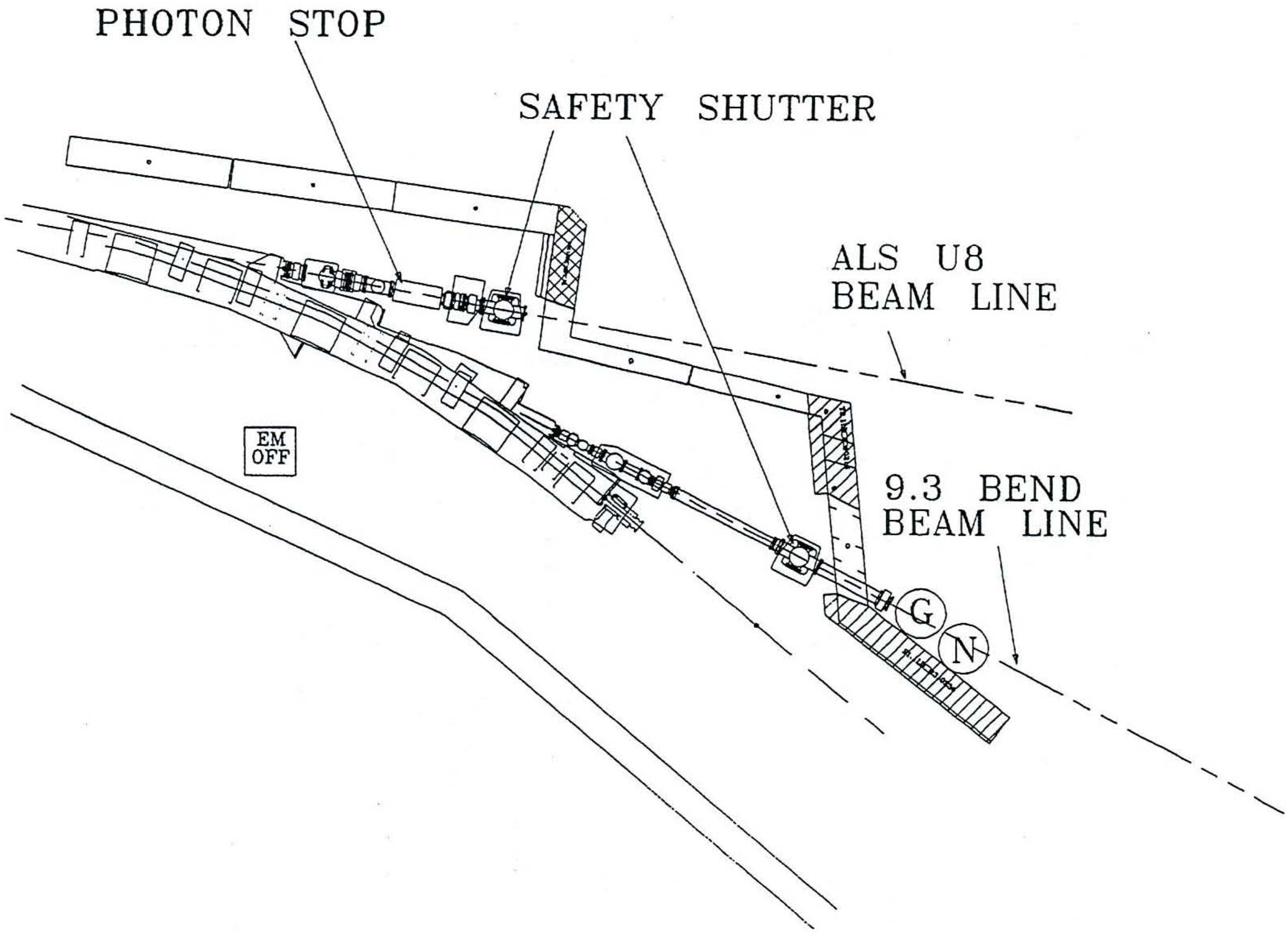


Figure 4-8. Detailed schematic diagram of one sector of the ALS storage-ring area showing the radiation shielding and the locations of the search/crash-off boxes (EM) and the neutron (N) and photon (G) detectors.

describe the radiation hazard. A location 39 m from the ALS center along the line connecting the centers of the booster and storage ring and 6 m above the floor (i.e.. in the second floor) is the nearest to both the booster and storage ring and is representative of the location where the maximum occupational dose would be received. A second location 125 m from the ALS center on the south side and a height of 2.4 m represents the LBL boundary where the maximum exposure of the general public would be received.

Table 4-1a summarizes the calculated maximum neutron dose equivalents at these two locations separately for radiation from each section of the accelerator complex and gives the total annual neutron dose equivalent at these locations from all the sections. The maximum annual neutron dose equivalents are calculated to be 114 mrem/year (1.14 mSv/year) on the second floor for the 2000-hour occupational year and 30.2 mrem/year (0.30 mSv/year) to the general public at the site boundary.

The consequences of the conservative assumptions about accelerator operations are most noticeable in the accumulated dose at the site boundary. The site-boundary value exceeds the design goal and required administrative reporting level of 10 mrem/year. In light of this result, the MORSE calculations were repeated [Sun, 1991] using the expected operating parameters of the ALS of 400 mA storage-ring current (rather than 800 mA), injection pulse rate of 1 Hz (rather than 4 Hz), and 6000 annual hours of operation (rather than 8760 hours). These changes result in a reduction factor of 0.086 that can be applied directly to the dose equivalents in Table 4-1a, as shown in Table 4-1b, giving a maximum environmental dose equivalent at the site boundary of 2.65 mrem/year (26.5 μSv/year), well below the current administrative reporting level (and design goal) of 10 mrem/year. In addition, some local shielding near the linac, collimators, and other components, and the shielding effect of equipment, furniture, partitions, etc. inside the ALS building were not considered. Consequently, the calculated dose equivalents are higher than those expected to be observed. It can therefore be concluded that the ALS shielding was adequately designed and complies both with radiological protection and environmental dose limits.

A potential additional factor to consider is that interaction of bremsstrahlung radiation with molecules in the air can generate radioactive isotopes by means of

Table 4-1a. Maximum annual dose-equivalent rates for the ALS for the most conservative operating conditions.

Maximum occupational dose equivalent(D.E.) on the second floor (39 m from ALS center and 6 m above ground floor, 2000-hour/year)					
Quantities	Linac +LTB	Booster ring	BTS	Storage ring	Units
D.E. from MORSE	4.30×10^{-5}	1.04×10^{-5}	1.33×10^{-6}	3.22×10^{-8}	mrem Joule^{-1}
Annual energy loss	1.39×10^{6}	2.88×10^{6}	1.95×10^{5}	6.23×10^{5}	Joule year^{-1}
Calculated D.E. rate	59.8	29.9	0.259	0.0200	mrem year^{-1}
Modified[a] annual D.E.	76.2	38.2	0.33	0.0255	mrem year^{-1}
Total annual D.E.			114		mrem Year^{-1}

Maximum environmental dose equivalent (D.E.) (125 m from ALS center and 2.4 m above ground floor, 8760 hour/year)					
Quantities	Linac +LTB	Booster ring	BTS	Storage ring	Units
D.E. from MORSE	2.74×10^{-6}	5.46×10^{-7}	1.24×10^{-8}	2.08×10^{-8}	mrem Joule^{-1}
Annual energy loss	6.09×10^{6}	1.26×10^{7}	8.57×10^{5}	2.72×10^{6}	Joule year^{-1}
Calculated D.E. rate	16.7	6.88	0.106	0.0566	mrem year^{-1}
Modified[a] annual D.E.	21.3	8.78	0.135	0.0722	mrem year^{-1}
Total annual D.E.			30.02		mrem year^{-1}

[a]Including 25% for intermediate-energy neutrons and 2.5% for high-energy neutrons.

Table 4-1b. Maximum annual dose-equivalent rates for the ALS for realistic operating conditions.

Maximum occupational dose equivalent (D.E.) on the second floor (39 m from ALS center and 6 m above ground floor, 2000 hour/year)

Quantities	Linac +LTB	Booster ring	BTS	Storage ring	Units
D.E. from MORSE	4.30×10^{-5}	1.04×10^{-5}	1.33×10^{-6}	3.22×10^{-8}	mrem Joule^{-1}
Annual energy loss	1.22×10^{5}	2.52×10^{5}	1.07×10^{4}	5.44×10^{4}	Joule year^{-1}
Calculated D.E. rate	5.15	2.62	0.0277	0.00175	mrem year^{-1}
Modified[a] annual D.E.	6.67	3.34	0.029	0.0223	mrem year^{-1}
Total annual D.E.			10.0		mrem year^{-1}

Maximum environmental dose equivalent (D.E.) (125 m from ALS center and 2.4 m above ground floor, 6000 hour/year)

Quantities	Linac +LTB	Booster ring	BTS	Storage ring	Units
D.E. from MORSE	2.74×10^{-6}	5.46×10^{-7}	1.24×10^{-8}	2.08×10^{-8}	mrem Joule^{-1}
Annual[a] energy loss	5.33×10^{5}	1.10×10^{6}	7.50×10^{4}	2.38×10^{5}	Joule year^{-1}
Calculated D.E. rate	1.46	0.602	0.00927	0.00495	mrem year^{-1}
Modified[b] annual D.E.	1.86	0.768	0.0118	0.00631	mrem year^{-1}
Total annual D.E.			2.65		mrem year^{-1}

[a]Calculation with storage-ring current 400 mA, injection rate 1 Hz, and use factor 0.7.

[b]Including 25% for intermediate-energy neutrons and 2.5% for high-energy neutrons.

photonuclear reactions. The principal products are nitrogen-13 and oxygen-15 from nitrogen-14 and oxygen-16, respectively [McCaslin, 1990a; Donahue, 1991a]. However, the ALS building, which is equipped with air conditioning in the storage ring tunnel and the experimental areas, affords sufficient mixing, dilution, and time delay to reduce exposure levels from these short-lived isotopes to less than 0.1 mrem/year in the building and less at the site boundary.

4.3.4 Present Shielding Configuration

Linac

Calculation of the dose rates expected during linac commissioning [McCaslin, 1990b] verified that the shielding was adequate, except for a region behind the linac beam dump, where rates were potentially significantly higher. To protect against the additional radiation, shielding blocks with total dimensions 10-feet wide by 10-feet high by 4 feet thick were placed outside the existing shielding wall behind the beam-dump area.

Storage Ring

The storage-ring shielding is ratcheted with side walls approximately tangential to the storage ring and transition walls perpendicular to the beamlines, which radiate tangentially from the storage ring. In addition, there are special shielding requirements in the injection area. In some locations, the storage-ring shield-wall and -roof thicknesses differ from the nominal values enumerated in Section 4.3.1, and in some locations lead shielding is added. The design goals for radiation exposure are 250 mrem/2000-hour work year (0.13 mrem/hour) for normal operation and 40 mrem/event for accidental loss of beam. It should be noted that the details of the storage-ring ratchet wall are not an issue for exposure to the general public at the site boundary, since the linac dominates the dose equivalent at this location.

The details of the present configuration of radiation shielding have evolved, but the design remains based on the calculations described in Sections 4.3.2 and 4.3.3. The evolution reflects in-depth examination of specific radiation issues, the outcomes of design and safety reviews, and the results of radiation monitoring during commissioning of the linac and booster synchrotron.

During the course of the ALS construction project, several internal and external reviews were held that included the shielding design, including formal DOE Safety Reviews in November 1989 [ALS, 1989d] and September 1991 [ALS, 1991b]. A major Conceptual Design Review was held in July 1990 [Melczer, 1990a], with a follow-up review in September 1990 [Melczer, 1990a]. The outcomes of these reviews led to the specific shielding configuration shown in Figure 4-9 [Matuk, 1991]. In addition, calculations were used to investigate specific radiation issues and to validate shielding-design features, as indicated by the references in the following paragraphs:

(1) The transition walls are designed for the worst-case scenario of a zero-degree beam perpendicularly penetrating the transition wall [Swanson, 1986; Melczer, 1991a; Donahue, 1992a;Donahue 1993]. Outside the injection region, the storage-ring transition wall comprises 1.5 feet of concrete, a floor-to-ceiling lead shield 3 inches thick, and a 9.2-inch band of lead, also 3 inches thick, centered at the orbit plane of the electron beam. The transition walls at insertion-device ports comprise monolithic, interlocked, hinged shielding blocks.

(2) To provide clearance for the insertion-device beamlines, the thickness of the side walls between the transition walls facing insertion-device and bend-magnet ports was reduced to 1 foot [Swanson, 1987; Melczer, 1991a; Melczer, 1991b]. All storage ring side walls have provision for 1 inch of lead shielding at a future date, should radiation surveys indicate a requirement for additional shielding against photons.

(3) To provide additional protection against injection loss, additional storage-ring wall and roof shielding is provided downstream of the region where electrons are injected from the booster synchrotron into the storage ring [Donahue, 1991b]. The thickness of the storage-ring shielding roof blocks is increased to 1.5 feet near the booster-to-storage ring transfer line, and the thickness of outside walls normally 1.5 feet and 1 foot, respectively, are increased to 2 feet and 1.5 feet, respectively, in much of this area. Inside walls are 3.3 feet thick in the injection area. Side walls in the storage-ring injection area have 2 inches of lead shielding, and transition walls

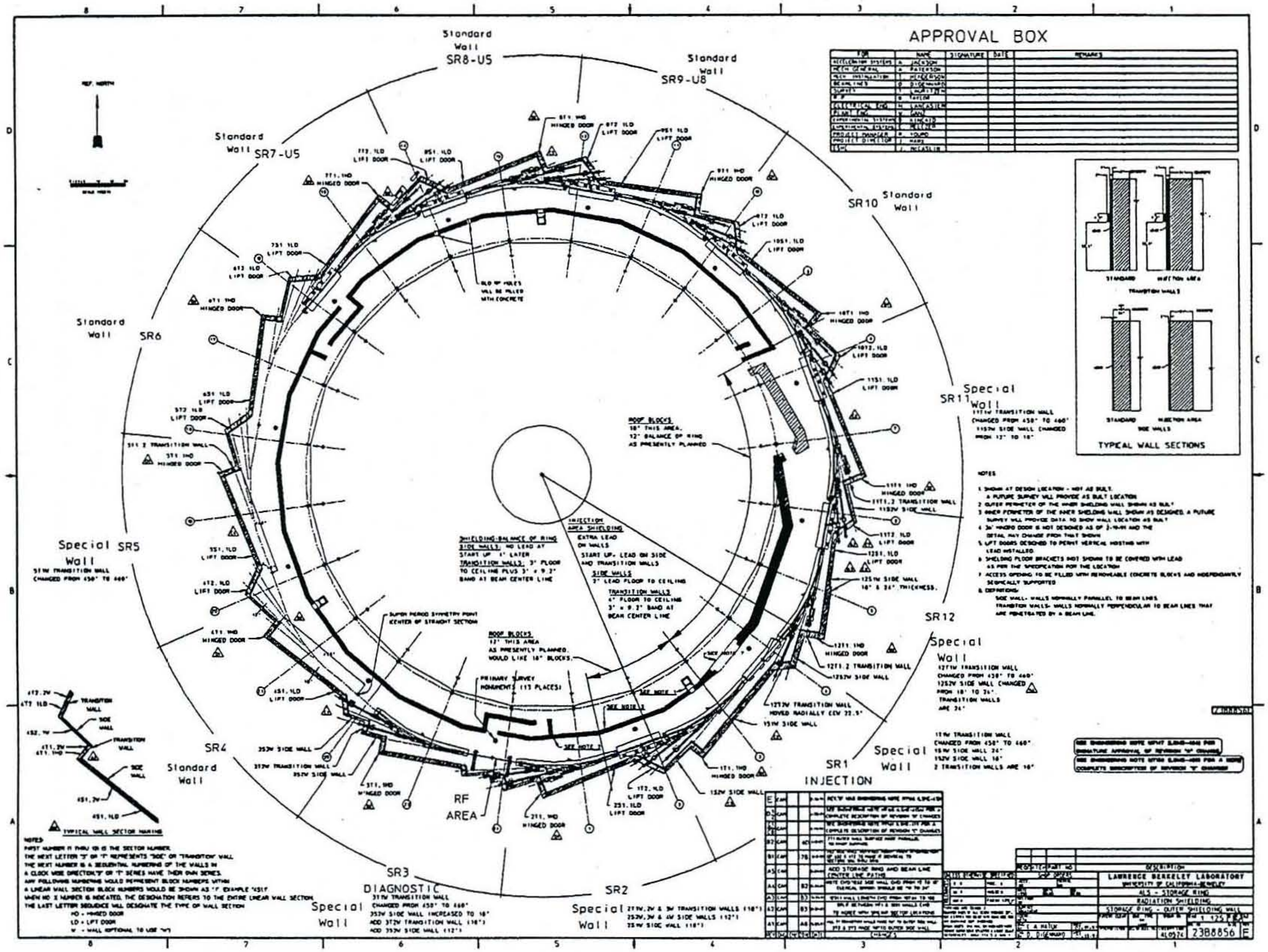


Figure 4-9. ALS Storage-ring shielding configuration.

have a floor-to-ceiling lead wall 4 inches thick and a 3-inch thick band of lead 9 inches high centered on the electron orbit plane.

(4) There are penetrations in the storage-ring walls for ventilation (HVAC) [Sun, 1990; Donahue, 1991c]. There is already sufficient shielding provided by the storage-ring components (such as the magnets) outside the injection area. Monitoring will be used to determined if additional lead shielding is needed in the injection area.

4.3.5 Validation of the ALS Shielding Design by Injector-Commissioning Experience

Commissioning of the accelerator systems started in October 1990 with the linac. Commissioning of the booster began in May 1991. Commissioning of the entire accelerator complex will continue through to April 1993. The initial stages of this activity took place at a time when construction and installation work was ongoing. Therefore, operation of the accelerators with beam occurred during off-hours, typically from 3:30 PM to 2 AM, when there were no concurrent construction activities.

Radiation monitoring at the site boundary and in the ALS building, as well as personal dosimetry data, during the injector commissioning show that radiation levels are, in general, lower than expected. This not only confirms the adequacy of the shielding, but suggests that electron beam losses are lower than estimated. Assuming the same pattern holds for the storage ring, the conclusion is that the reduced radiation levels associated with the lower beam losses makes operation of the ALS even less hazardous.

Radiation Monitoring at the Site-Boundary

There is a single radiation-monitoring station at the LBL site boundary located about 125 m south of the ALS-building center. Both neutrons and photons are detected. There are four site-monitor channels whose pulses from the site-boundary station are logged on a computer at 10-minute intervals. Data from this station has been continuously accumulated over a 2-year period, thereby including intervals when the ALS injector complex was being commissioned and intervals when there was no accelerator activity. By scanning the data to search for intervals with counts above a minimum representing the time-dependent background, the presence or absence of radiation above background could be verified. Preliminary analysis of histograms generated for the observation period from January 1 to December 14, 1992 show that neither neutron nor photon readings showed any discernible rise above background, with the exception of isolated spikes that do not correlate with ALS commissioning operations [de Castro, 1992]. Further statistical analysis will be done by the LBL Environment, Health, and Safety Division to verify these findings. Because of the extensive operation of the injector complex during commissioning, radiation sufficient to have an impact on the administrative reporting level of 10 mrem/year would be readily observable.

These findings constitute preliminary evidence that the operation of the ALS injector has no measurable effect on the radiation level at the site boundary. Because the injection system is the primary source of radiation at the site boundary, these results suggest that the entire facility will likewise have no measurable effect.

Radiation Monitoring in the ALS Building

During commissioning of the injector complex, radiation surveys and monitoring were carried out in accordance with LSP-023 Accelerator Initial-Operation Radiation Safety Check List [Massoletti, 1992a], as described in Section 6.5.1. Measurements during the period of linac commissioning since February 1991 and during the period of booster commissioning beginning in May 1991 make it possible to test the adequacy of the shielding and to compare the survey results with the predictions of calculations of the various contributions to prompt radiation fields [McCaslin, 1986].

For the linac, comparison between the predicted dose rate and measurement showed that radiation levels were generally lower than expected. During acceleration of electrons from the electron gun down the linac, electrons are lost along the accelerating structure at energies ranging from 120 keV to 50 MeV. The radiation shielding was designed to reduce the levels immediately outside the shielding to less than 5 mrem/hour. In most areas, the measured radiation levels were well below this value. On the linac roof, typical levels are 0.2 to 1 mrem/hr [Collins, 1992a]. When the beam was mis-steered, however, photon-radiation levels up to 50 mrem/hr were measured above the linac-to-booster (LTB) transfer line.

In localized areas where measurements showed that the radiation levels exceeded 5 mrem/hour, local shielding of lead and concrete was added and easily reduced the dose rate to below the design goal. For example, outside the beam-splitting magnet in the LTB line, fields up to 40 mrem/hr were observed before a lead shield was installed at the vee of the line. Since then, radiation levels have not exceeded 1 mrem/hr outside the shielding. Above the Faraday cup, a thin spot in the shielding created by a conduit gave rise to radiation levels of about 5 mrem/hr when beam was directed to the Faraday cup. Local shielding was added to this location, which reduced the combined photon and neutron radiation level to about 1 mrem/hour.

Booster commissioning involved optimizing the capture of beam from the linac at 50 MeV and ramping the beam energy from 50 MeV to 1.5 GeV. Beam losses at this time were at any or all energies in this interval. The radiation shielding faces its most demanding job when the full beam current has been accelerated to full energy. The shielding around the booster is uniform and sufficient to reduce point-loss doses from the loss of the full beam at 1.5 GeV to less than 75 mrem/hour adjacent to the booster shielding. The design goal for uniform losses is 0.2 mrem/hour.

Once efficiently accelerated and extracted, the 1.5 GeV beam will either be steered into a well-shielded beam dump, as in normal tune-up operation, or directed down the booster-to-storage ring (BTS) transfer line to the storage ring. In the former case, the shielding is sufficient to permit local temporary occupancy and to meet the site-boundary condition. Radiation monitoring in the most sensitive areas is used to determine where extra radiation shielding would be beneficial.

Measured dose rates during injection into the booster were minimal. A 50-MeV point loss in the booster was predicted to give 10 mrem/hour on the booster roof. Measured dose rates were about 0.1 mrem /hour, suggesting that the loss was distributed (as was also predicted) and/or that significant shielding is provided by the magnet structures, for which credit was not taken in the calculations.

During ramping from 50 MeV to 1.5 GeV, uniform losses were measured to be, typically, less than 0.1 mrem/hour or less. Maximum point losses of 200 mrem/hour were measured at a location tangential to the BTS extraction-septum area during a commissioning period when there was incomplete extraction. Individual hot spots were also found with higher radiation levels during abnormal operating conditions, such as mis-steered beam or non-standard tunes and tune resonances. One hot spot of about 5,000 mrem/hr was observed over a measurement time of 1 minute. In this instance, an exclusion area was made around the hot spot.

Table 4-2 summarizes the comparison between calculated and measured radiation values from operational surveys.

Table 4-2. Calculated and Measured Radiation Doses during Injector Commissioning

Location	Calculated, mrem/hour	Measured, mrem/hour
Linac	1.25	1 (typical, roof, high-energy end) 50 (roof, small hot spot with beam mis-steered)
Booster, point loss	75	200 (commissioning studies)
Booster, uniform loss	0.05	<0.1

Radiation monitoring by thermoluminescent detectors (TLDs) located at the periphery of the ALS building provide additional information on radiation levels. Data has been analyzed for the period from October 1, 1991 to May 1,1992 [Collins, 1992b]. The data from May 1, 1992 to December 1, 1992 has been collected and will be analyzed in the near future.

Thus far, there is no observable increase in integrated radiation above background at the building periphery. Based on typical background rates since the TLDs were previously annealed, none of the readings is outside the 95% confidence interval (±2 sigma interval) for null readings.

In sum, operation at design power levels produces sustained radiation fields at levels lower than those calculated when large areas of the shielding are involved. Although measured radiation levels at small hot spots have exceeded calculated values, these have been readily reduced by the addition of localized shielding.

Personal Dosimetry

All ALS personnel working in the ALS building are required to wear personal dosimeters for photon and neutron radiation. Film badges are exchanged monthly. Data on occupational radiation exposures around the ALS have been analyzed for the period January through September 1992 for an average occupancy of 30 persons comprising physicists, accelerator operators, and electronics maintenance technicians.

During this nine-month period, no neutron radiation doses were recorded. Photon radiation doses were distributed as follows for a total of 270 person-months of integrated exposure [Jackson, 1992a]:

Dose, mrem/month	10-20	21-30	31-40	>40
Number of times dose occurred (person-months)	17	3	1	2

In reviewing this data, factors to be noted include:

(1) Only one person (a radiation health physicist) recorded a measurable photon radiation dose in more than one month.

(2) In at least two instances, the exposed worker spent time around other radiation-producing accelerators.

(3) Of the two instances of doses greater than 40 mrem/month, one involved exposure to low-energy x-rays not associated with accelerator operation, and one was considered to be anomalous because no co-worker received any measurable dose.

In sum, radiation doses to workers around the ALS are extremely low. Less than 10 percent of radiation workers received more than the LBL Environment, Health and Safety Division's lower reporting level of 10 mrem/month for photon radiation. The exposure profile is consistent with that expected from previous experience at LBL.

4.3.6 Bremsstrahlung Radiation in the Beamline Areas

ALS beamlines require holes to be opened in the storage-ring shielding. In addition to the synchrotron radiation, the holes will allow hard bremsstrahlung to pass through to the experimental floor. Based on safety requirements currently in force at the National Synchrotron Light Source, initial guidelines for designs for beamlines were developed [Warwick, Melczer, Perera, and Heimann, 1990]. Installation of beamlines that satisfy these requirements is now in progress. Radiation shielding designs are subject to design and safety reviews. Typical among the major reviews for LBL-engineered beamlines are a Front End Radiation Safety Requirements Review that was held in February 1991 [Johnson, 1991] and a Beamlines Preliminary Design Review that was held in September 1992 [DiGennaro, 1992]. All beamline designs, both LBL- and user-engineered are subject to review by the Beamlines Review Committee, as described in Section 6.3.4 . Calculations were used to investigate specific radiation issues and to determine criteria for shielding designs [Swanson, 1986; Melczer, 1990b; Melczer, 1991c; Donahue, 1992b; Donahue, 1993]. During beamline commissioning, radiation monitoring will be used to determine the need for supplementary shielding.

The shielding design in the beamline area is based on the following factors:

- Apart from the hole in the shielding, the storage-ring shield wall is assumed to give adequate protection against all radiation from the ring.
- A radiation safety shutter will close the hole during storage-ring injection and when the beamline is not in operation. The closed shutter will intercept all lines of sight from inside the storage-ring shield wall through the hole.
- The possibility that the shutter will provide inadequate shielding against neutrons will be dealt with if neutron radiation is observed; it has not been a problem at other facilities.
- All parts of the shutter and any extra shielding associated with it will be inside the shield wall.
- The shutter will be fail-safe and will be positively sensed in the closed position.

When the shutter is open, bremsstrahlung passes through to the experimental floor, requiring additional shielding at certain locations and the establishment of exclusion areas by means of physical barriers or administrative procedures. In many cases, the physical barrier will be the beamline vacuum chamber itself. Beamline design factors pertaining to the open-shutter condition include:

- Analysis at the National Synchrotron Light Source [NSLS, 1982] indicates that the bremsstrahlung yield down a beamline over one year of normal operation is greater than that from a single worst-case vacuum accident. Protection against normal operation is therefore the basis of the shielding design.

- All lines of sight from the bremsstrahlung source will be collimated or blocked by shielding to contain the bremsstrahlung inside the portion of the beamline to which access is excluded.

- The region of the experimental floor within the collimated direct bremsstrahlung beam will be an exclusion zone. Physical barriers will keep all body parts of personnel from entering this zone. Where the beamline vacuum chamber does not contain the bremsstrahlung, external barriers and interlocks will be required.

- Bremsstrahlung can be scattered outside the collimation zone by massive objects (mirrors, flanges, etc.) Scattered radiation will be dealt with as required during commissioning the beamline.

4.3.7 Validation of Personnel Safety Shutter

A personnel safety shutter includes an 8-inch block of tungsten, which is designed to provide bremsstrahlung attenuation equivalent to the transition wall shielding. The shielding performance of the personnel safety shutter in Beamline 8.0 was tested by closing vacuum valves in the storage ring and observing the resulting radiation at the end of representative location at the end of a beamline and outside the shielding [Collins, 1993a]. This scenario simulates the worst case accident, a thin-target source directly irradiating a beamline.

In the first part of the test, a vacuum valve at the upstream end of the straight section in Sector 8 of the storage ring was closed during injection of 7 mA of current from the booster synchrotron. The valve created a thin-target source of bremsstrahlung that was most intense in the straight section of Sector 8 and hence illuminated Beamline 8.0. The personnel safety shutter attenuated the radiation to less than 1 mrad/hour photons and less than 0.1 mrem/hour neutrons at the end of the beamline.

In the second part of the test, a vacuum valve in Sector 3 of the storage ring was closed, again creating an intense source of bremsstrahlung in the Sector 3 straight section. At 0.8 mrad/hour photons and less than 0.1 mrem/hour neutrons, the results of measurements outside the Sector 3 shielding (there is no Beamline 3.0) were comparable to those made for Sector 8.

The acceptance criterion for the personnel safety shutter is that it provide bremsstrahlung attenuation equivalent to the shielding. These test results satisfy this criterion, indicating that the performance of the personnel safety shutter is acceptable.

4.3.8 Shielding for the Beam Test Facility

Shielding materials and thicknesses required for the BTF, which have been calculated assuming very aggressive operation of the linac, are adequate to limit occupational worker exposure to 100 mrem/year [Donahue, 1992d]. For a normal operating schedule of 1000 hours/year, this corresponds to an hourly dose limit of 0.1 mrem/hour. The shielding comprises concrete walls 7 feet thick in most locations and concrete roof blocks 4 feet thick supplemented with lead and polyethylene where necessary . The concrete shielding is 8.25 feet thick in front of the BTF beamline, where a beam dump is located. Locations of the lead and polyethylene include 4 inches of lead on the roof above collimators and scrapers, 7 inches of lead and 21 inches of polyethylene on the roof above the beam dump, 3.2 inches of lead and 14 inches of polyethylene between the beam dump and the entrance labyrinth, 4 inches of lead by the first bend magnet in the BTF vault, and 3 inches of lead by the bend magnets in the linac cave. Figure 4-10 shows the BTF layout and shielding.

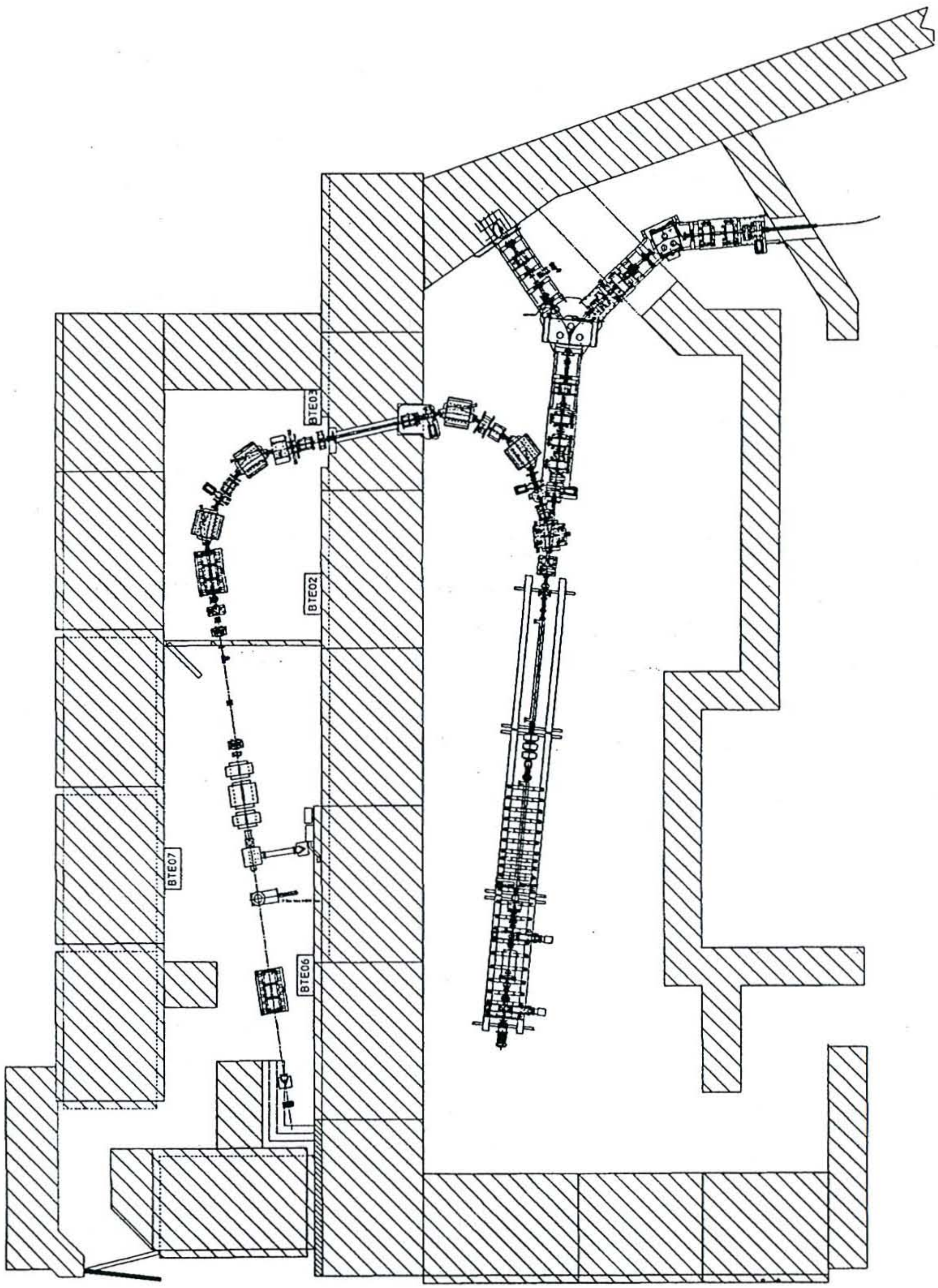


Figure 4-10. Detailed schematic diagram of the Beam Test Facility area showing the radiation shielding and the locations of the radiation gates and the crash-off boxes.

4.4 Radiation Safety System

The radiation safety system is the major control subsystem responsible for the overall personnel radiation safety at the ALS. The elements of this system comprise the interlock logic, operator station, and status displays associated with each component of the overall ALS architecture. All of the major accelerator subsystems are associated with one or more radiation safety system controller(s).

The ALS consists of three major parts: the injection system (electron gun, linac, booster synchrotron and transfer lines), the storage ring, and the beamlines and experimental areas. Each of the major parts of the ALS has three areas of concern regarding radiation safety: access control, area monitoring, and control-room management.

The radiation safety system is designed to allow independent operation of these major parts while providing the required personnel protection. Functionally, each of the three major parts are linked to inhibit operation should a radiation hazard exist in an occupied area as a result of operating an adjacent part. For example, it is desirable to be able to operate the linac and booster and at the same time have access to the storage ring for maintenance. Administrative procedures, radiation monitoring, and training are also considered part of the safety system.

4.4.1 Radiation Safety System Design

The design of the radiation safety system has been subject to an extensive series of internal and external reviews [ALS 1992b and references therein], including DOE Project Safety Reviews in November 1989 [ALS, 1989d] and September 1991 [ALS, 1991b]. The most recent review is the ALS Accelerator Interlock and Safety Systems Operational Review in July 1992 [ALS, 1992d]. Safety-system modifications are governed by EE 02-01 Procedure for Design and Modification of Personnel Safety Systems [Jones, 1993d].

The design philosophy behind the radiation safety system is that it must protect personnel from all plausible hazards related to the operation of the linac, booster, transfer lines, storage ring, beamlines, and experimental areas. The primary hazards addressed are those associated with radiation, high voltage, high-stored-energy devices, and moving mechanical parts or assemblies. To achieve its aim, such a system must be fail-safe, redundant, testable, reliable, and simple.

Features of the radiation safety system design include:

- Totally redundant control of all systems and devices, such as rf, magnets, beam stops, etc. Redundancy requires more than one level of checking and protection. The long history of safe operation at facilities with two levels of redundancy led to the adoption of the same number at the ALS. Redundancy is accomplished by means of independently wired relay systems with parallel functions.

- No solid-state devices in critical personnel protection circuits. A simple hard-wired electromechanical system was selected. Switches of the microswitch type are used to sense position (open or closed). When semiconductors are used in applications where a failure could render the system inoperative or result in a hazardous situation, the system is designed to fail in the safe condition. Improvements have been made to existing "tried and true" components, such as the use of light emitting diodes in place of incandescent lamps.

- Testable. Testable means that any single system error or failure must be detected before other failures occur that might produce a hazardous situation. This requires that all individual circuits and chains be checked to determine whether they are reporting the same status.

- System voltage is 24 V DC. The radiation safety system uses the industry-standard 24-V DC control voltage. Numerous components are therefore available for design.

- Separate routing of wiring. Wiring for non-safety equipment is not allowed in safety-system wireways.

- No wiring in open ladder trays. Wiring is protected by enclosed steel wireways or conduits.

- Tamper resistant. Equipment racks, cross-connection racks, and cable junction boxes are locked and key-controlled.

4.4.2 Operation of the Accelerator Protective Interlock System

Each of the major parts of the ALS has three major areas of concern for radiation safety: access control, area monitoring, and control-room management.

"Controlled access" designates a system of interlocked, physical barriers to prevent personnel from entering hazardous areas. If these barriers are violated, all hazardous equipment is turned off, and all sources of radiation are secured. Controlled access is achieved by locked gates at entrances to the parts of the ALS accelerator complex. All gates are provided with switches to indicate whether they are closed and latched. Opening of any gate in this area causes the shutdown of appropriate equipment. Each gate also has a key tree and a lighted sign to indicate the accelerator status. Each person entering under controlled access is required to take a key. The action of taking a key prevents operation of the accelerator, which cannot resume until all persons having keys have exited and returned their keys to the tree.

Crash-off/search boxes in the accelerator enclosures are dual-function devices. If any "crash-off" box is activated, all radiation and large magnet power supplies are rendered safe by appropriate equipment shutdowns. Activation of the "search" portion of each box is part of a search-and-clear chain, which demands that a search be made of the area in a prescribed manner (and the boxes reset in a prescribed sequence) before hazardous equipment can be made operational once again. OP 02-07 Accelerator Search and Secure Procedure [Daly, 1993] and LSP-022 Accelerator Controlled Access Procedure [Massoletti, 1992b] contain requirements for carrying out searches of the accelerator areas.

Active neutron and photon area monitoring of radiation outside the shielding where personnel are allowed to work is continuous. LSP-023 Accelerator Initial-Operation Radiation Safety Check List contains requirements for radiation monitoring (also see section 4.4.4 below). Excessive radiation or monitoring-equipment failure will turn off all sources of radiation under all circumstances.

A brief description of how the protective interlock system addresses these concerns for the major parts of the ALS follows:

Electron Gun/Linac

The radiation safety system for the electron gun and linac (hereafter together called the linac) is designed with one main access and one emergency escape exit gate. The position of each gate is sensed by redundant microswitches. During normal operation, access to the linac via the main gate is controlled by the main control room. A two-way audio communications system, a closed-circuit television system, a "key tree" and a lighted status sign are located adjacent to the gate. Access inside the shielding requires communications with, and surveillance by, the main control room. The following sequence of operations must occur for controlled access to take place:

(1) The main control room disables linac operation by switching it to the safe mode;

(2) The person entering must take a key from the key tree;

(3) The control room must log the access and release the gate for entry.

These actions prevent either local or remote operation of the linac. Inside the shielding are three "crash-off/search" boxes. The main access and emergency exit gates have emergency "crash-off/in" release mechanisms. Activation of a crash-off box or crash-off/in gate release prevents the operation of the linac. Restarting requires a search of the linac shielding. The search requires a key from the main control room and a search sequence such that the key is used to reset the crash-off/search boxes in a manner ensuring that a complete search has been made. The linac can only be operated after a search-and-secure procedure has been completed and the key returned to its keyswitch cache in the main control room.

Radiation monitoring outside the shielded linac enclosure consists of x-ray and neutron detectors. Radiation detected above allowable limits in this area prevents operation of the linac.

Figure 4-6 shows locations of the features of the safety system in the linac area; Figure 4-11 is a block diagram of the linac radiation-safety interlock system.

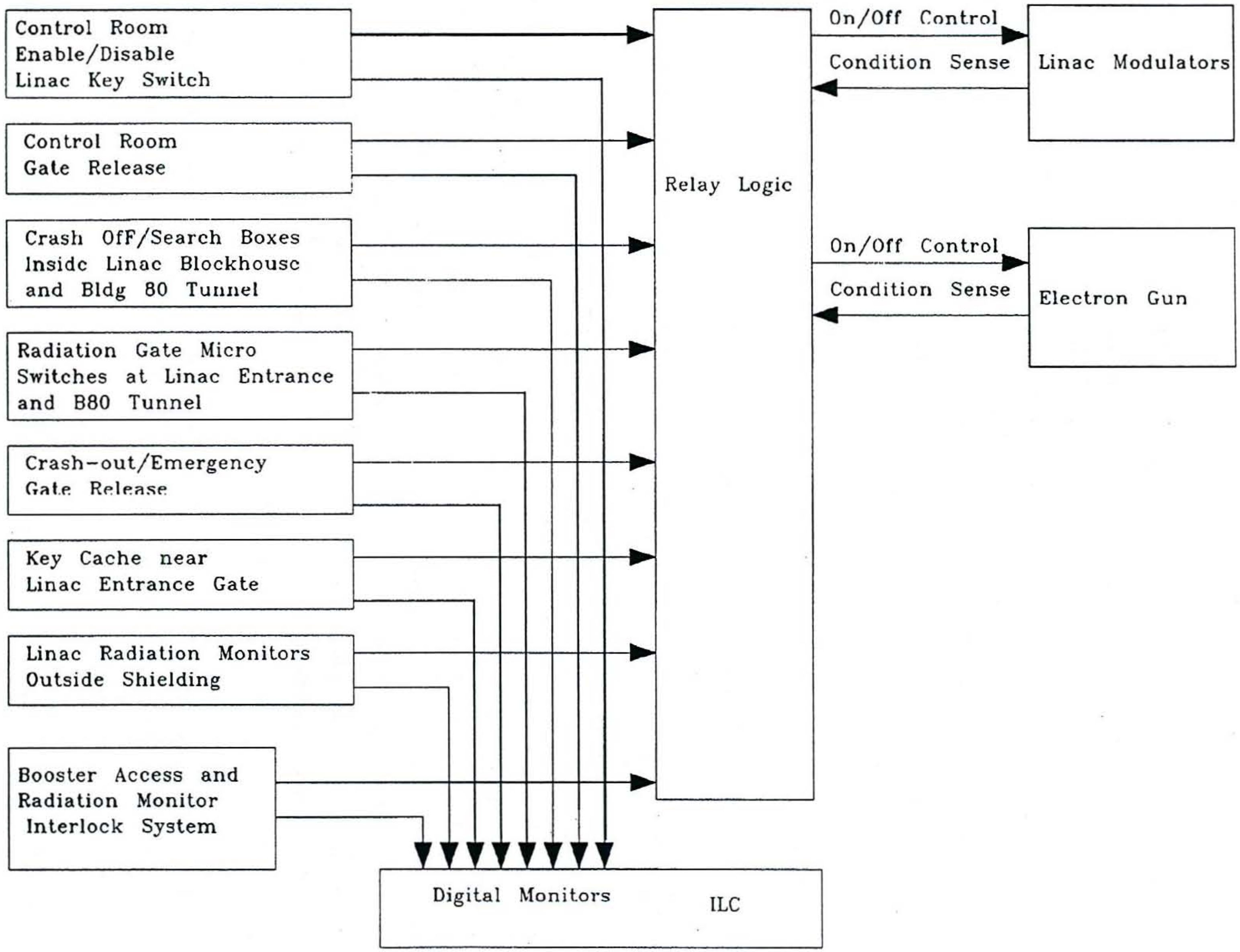


Figure 4-11. ALS radiaton-safety interlock system for the linear accelerator

Booster Synchrotron

The booster has two main access gates with access-control systems identical to those described for the linac. The booster has six crash-off/search boxes. After activation of a crash-off box, restarting requires two persons with two keys from the main control room to perform a search-and-secure procedure. The search is done in a controlled sequence as with the linac. Controlled access for testing and maintenance can be granted. The following sequence of events must occur for controlled access to take place:

(1) The main control room disables linac and booster operation by switching it to the safe mode;

(2) The person entering must take a key from the key tree;

(3) The control room must log the access and release the gate for entry.

These actions prevent the operation of the linac and booster.

Radiation monitoring outside the booster shielding consists of x-ray and neutron detectors. Radiation detected above allowable limits in this area prevents operation of the linac and booster.

Figure 4-7 shows locations of the features of the safety system in the booster-synchrotron area; Figure 4-12 is a block diagram of the radiation-safety interlock system for the booster.

Storage Ring

The system is designed to allow operation of the linac and booster while portions of the storage ring are accessible for testing and maintenance.

The storage ring has three main access gates at sectors 10, 2, and 6 with access-control systems identical to those described for the linac and the booster. The entrance gate at sector 10 interlocks the injection systems and the storage-ring rf system during

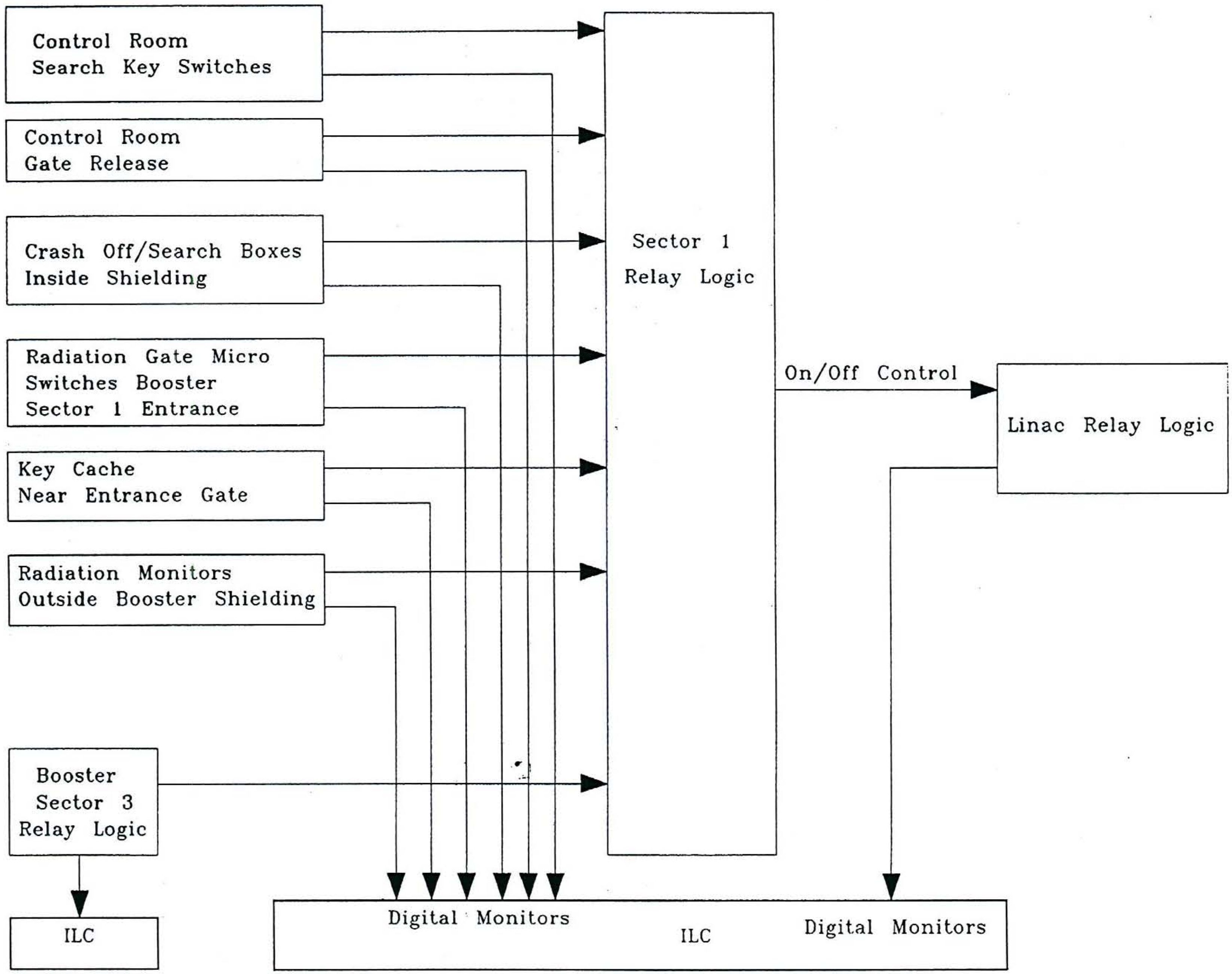


Figure 4-12. ALS radiaton-safety interlock system for the booster synchrotron.

normal operation. The entrance gate at sector 2 interlocks the storage-ring rf systems during low-power tests, high-power tests, and normal operation. The entrance gate at sector 6 interlocks the storage-ring rf system during normal operation. The hinged concrete shielding blocks in the outer shielding wall are interlocked to the zone in which they reside.

The storage ring has three internal gates: one associated with the booster-to-storage ring injection area, one associated with the storage-ring rf system, and one serving both areas. Internal gates A and B prevent access to the storage-ring BTS area while the injection system is being tested and the beam goes to the BTS beam dump. The BTS area then becomes part of the injection interlock system, and the electron gun is inhibited if the area is not secure. Internal gates B and C prevent access to the rf-cavity area during full-power testing and normal operation. The area can be accessed during low-power testing.

There are 12 crash-off/search boxes. Boxes in each of the three storage-ring zones operate independently. After activation of a crash-off box, restarting requires two people with two keys from the main control room to perform a search-and-secure procedure. The search is done in a controlled sequence as with the linac. The following sequence of events must occur for controlled access to take place:

(1) The main control room inhibits operation of the injection system, if appropriate, by switching it to the safe mode;
(2) The person entering must take a key from the key tree;

(3) The control room must log the access and release the gate for entry.

Radiation monitoring outside the storage-ring shielding consists of x-ray and neutron detectors. Radiation detected above allowable limits in this area prevents operation of the storage-ring rf and prevents injection into the storage ring.

Figures 4-5 and 4-8 show locations of the features of the safety system in the storage-ring area; Figure 4-13 is a block diagram of the radiation-safety interlock system for the storage ring.

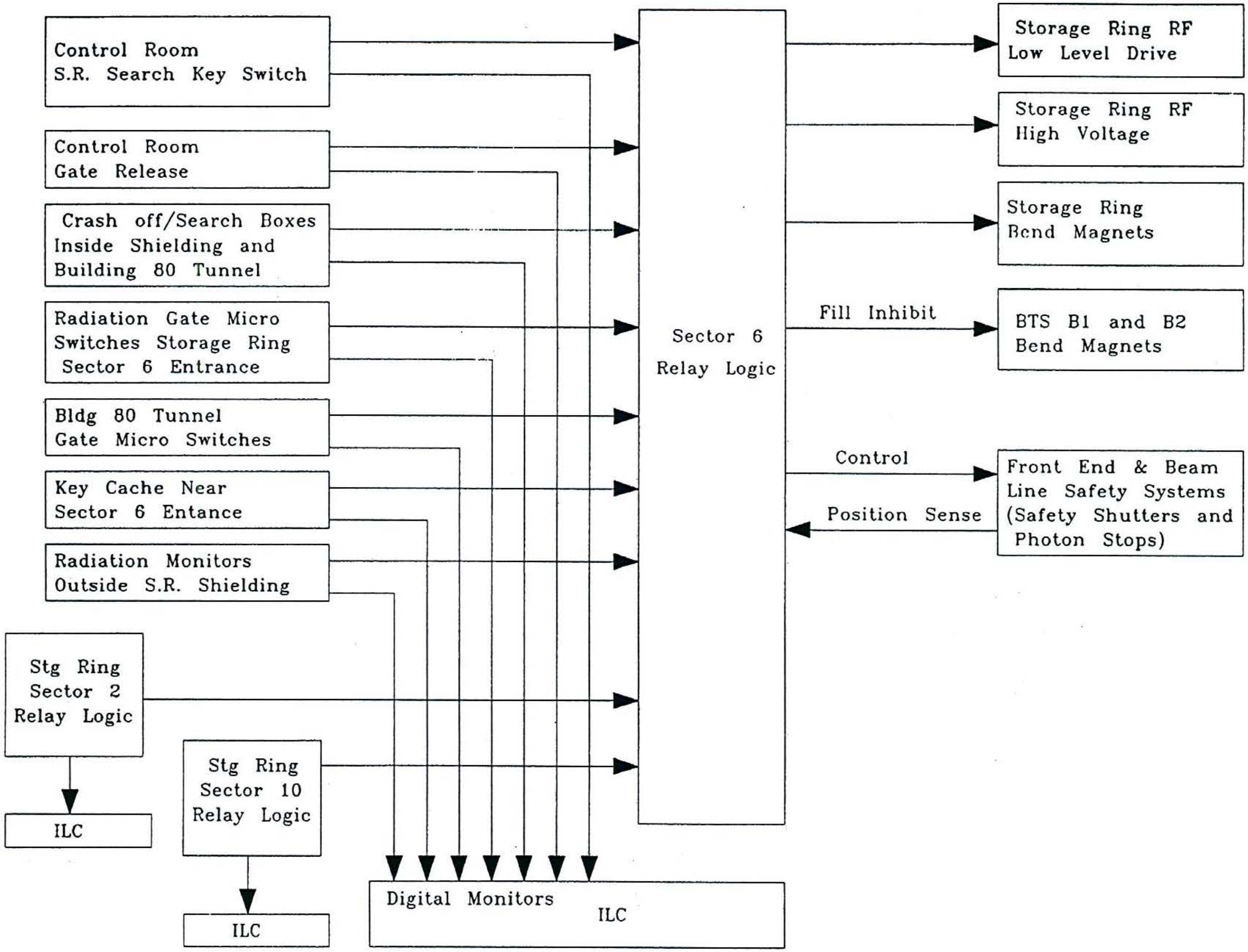


Figure 4-13. ALS radiation-safety interlock system for the storage ring.

TURN PAGE

FIG. 4-13

4.4.3 Beamline Radiation Safety System

The beamline radiation safety system comprises subsystems for each of the one or more branch lines associated with a beamline and the end stations associated with each branch line [Cork, Young, and Ritchie, 1992]. Note that the beamline front-end components are contained within the storage-ring shield wall and are thus controlled by the storage-ring radiation safety system. However, the radiation emanating from the beamline front ends is moderated by the branch-line radiation safety subsystems. Figure 4-14 diagrams the beamline radiation safety system.

Branch-Line Radiation Safety Subsystem: The branch-line radiation safety subsystem is responsible for control of the radiation passing into the branch line and for control of access to areas with potentially elevated radiation levels during normal operation. The personnel safety shutter that is located just inside the storage-ring shield wall controls passage of the radiation. The shutter controller responds principally to commands from the front-end beamline equipment protection system (e.g., to close the shutter during injection or to open/close the shutter in response to operator requests). A personnel safety shutter keyswitch may be used to enable or disable individual branch lines, in most cases independently of other branchlines.

During the filling of the storage ring, water-cooled photon shutters and safety shutters will be inserted in the photon beamlines. These devices will be monitored by redundant position-indicating microswitches that prevent filling of the storage ring whenever any improper photon stop, water flow, or safety shutter condition is detected. The system is designed so that the safety shutters cannot be closed unless the photon shutters are closed, and the storage ring cannot be filled unless both are closed. Self-checking ensures detection of a failure in one of the redundant circuits. A failure will not shut down the machine, but it will prevent further filling of the storage ring.

Access to beamline areas with potentially elevated radiation levels is controlled by enclosures with redundant interlock chains and emergency crash-off boxes.

End Station Radiation Safety Subsystem: In some cases (e.g., when an x-ray hutch is required), a separate end-station radiation safety subsystem, which is functionally identical to the branchline radiation safety subsystem, controls radiation passing into

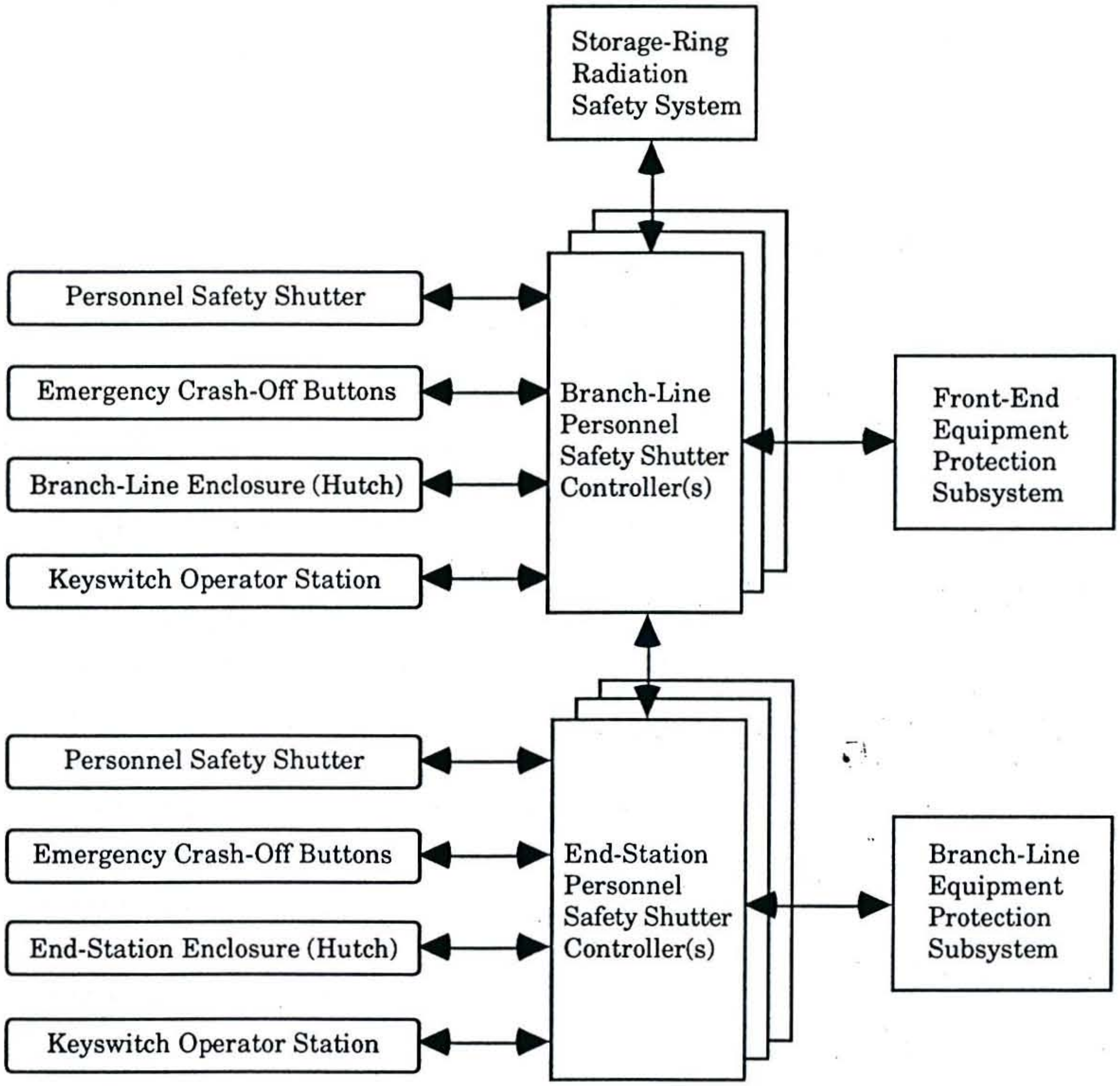


Figure 4-14. Diagram of the beamline radiation safety system showing branch-line and, where applicable, end-station subsystems.

the end-station region. For most beamlines, the exit valve will be controlled by a lock and key. These controls protect the experimenter from accidental exposure to synchrotron radiation and provide a control interface for enabling/disabling beam to the experiment.

Access to the beamline and experimental area will be controlled, and each person entering will be required to wear a personal dosimeter. Administrative procedures will be established for education of users about entry requirements. Use of roll-up doors for delivery of large equipment will be controlled and monitored by the operations staff.

Radiation monitoring in the beamline and experimental areas is by means of the same system used to monitor radiation outside the storage-ring shielding and consists of x-ray and neutron detectors. Active radiation monitors with preset trip levels of 10 mrad/hour are part of the interlock chain and prevent operation of the storage-ring rf and bend-magnet systems. Thermoluminescent dosimeters, for backup, will also be placed around the building. In addition, all personnel are required to carry their personal dosimeters (photon and neutron), worn on the upper torso, at all times.

4.4.4 Beam Test Facility Radiation Safety System

The BTF radiation safety system follows the principle adopted for the ALS accelerator radiation safety system (see Section 4.4.1). The system is designed to allow access to portions of the BTF vault when the linac is operating as part of the ALS injector system. For this purpose, in addition to the access gate to the BTF vault, a second access gate is installed downstream of the penetration through the wall separating the linac and the BTF line, thereby separating the vault into A and B caves as shown in Fig. 4-10. The BTF radiation safety system provides interlock protection against entrance into cave B but permits access to cave A during operation of the linac for ALS storage-ring injection, and it provides interlock protection against entrance into cave A during operation of the linac for the BTF. The system been approved by an LBL review team [Bailey and Krupnick, 1993; Stevenson, 1993].

During normal operation of the BTF, both A and B gates will be closed. When the ALS injector is in operation, the linac will be on, but no beam will be present in the BTF vault. The B gate will be closed. A flashing red beacon, red lights within the B cave, and a sign warning personnel not to enter will be present.

To enter the B cave, the control room must shut down the linac. If the B gate is opened while the linac is operating, the linac interlock chain will be broken and the linac turned off. To return the linac to operation, a search of the B cave is required to complete the BTF interlock chain, which in turn allows the linac interlock chain to be completed. The search must be conducted by at least two trained personnel. Search push buttons on two crash-off boxes on opposite walls of the cave must be pushed simultaneously, which requires a two-person search team. The B gate must be closed within 10 seconds of pushing the crash-off box buttons.

To enter the A cave, the power supplies of the bend magnets that divert the beam into the BTF vault must be turned off by pushing an on-off button on the safety rack at the entrance to the BTF vault. Two keys are required to unlock the entrance gate. Pushing a release push button in the safety rack allows removal of the A key, which is inserted into a kirk key assembly at the gate. Inserting the A key allows removal of the B key, which when removed releases the entrance gate. The A key cannot be removed from the kirk key assembly while the B key is being used. To return to BTF operation, the gate must be closed after a two-party search is conducted. Crash-off boxes on opposite walls, one with a push-button and one with a key switch, must be activated simultaneously, and the gate must be closed within 30 seconds. The B key must be reinserted into the kirk key assembly and the A key returned to the safety rack. Turning the A key activates the red lights in the cave and completes the circuit for the on-off switch. Pushing the switch causes a 60-second alarm to sound before energizing the bend-magnet power supplies.

4.5 Safety Analysis of Radiation Hazard Events

Radiation hazards potentially exist at the LBL site boundary and within the ALS building. It is assumed that the general public has access to the site boundary. Access to controlled areas within the ALS building is governed by the ALS Accelerator OSP [Massoletti, 1992c] with additional guidance provided by LSPs, as described in Section 6.5.4.

The methodology described in Section 4.1 was applied to each identified radiation hazard event. Each event analysis included determining the initiating occurrence, possible detection methods, the safety features that might have prevented or mitigated the event, the probability of the event occurring, and the possible consequences.

Based on the discussion in the following sections, a hazard control matrix was constructed (Table 4-3). The matrix shows that ionizing-radiation hazards exist throughout the facility. The matrix also indicates mitigation and control features operative in the various parts of the facility.

Using the guidance provided in SAN Management Directive 5481.1A for conducting safety analyses, the consequences and probability of each hazard were rated by levels. Table 4-4 summarizes the consequence levels, and Table 4-5 summarizes the probability rating levels. The overall risk associated with each specific hazard was determined using these rating levels and the risk matrix (Table 4-6) also provided in SAN MD 5481.1A. Table 4-7, which summarizes the risk assessment for exposure to ionizing radiation according to this methodology, shows that the ALS facility operates within the risk envelope for low-hazard facilities as defined in SAN MD 5481.1A.

4.5.1 Hazard Event: Exposure to Ionizing Radiation at the Site Boundary

Initiating Occurrence

The maximum exposure to a member of the general public occurs at the LBL site boundary. Prompt radiation relevant to the site boundary from operation of the accelerator systems comprises bremsstrahlung radiation and neutrons, which are produced during both normal and abnormal operating conditions.

Method of Detection

Radiation is monitored by photon and neutron detectors in a station located 125 m south of the ALS building center at the LBL site boundary.

Table 4-3. Hazard Control Matrix

Hazard Type	Accelerator Area	Experimental Floor	Site Boundary
Exposure to ionizing radiation at the site boundary	NA	NA	13, 14
Exposure to ionizing radiation outside the accelerator enclosures	NA	1, 2, 3, 11, 12, 13, 14	NA
Exposure to ionizing radiation inside the accelerator enclosures	1, 2, 3, 9, 12, 13	NA	NA
Exposure to synchrotron radiation	NA	2, 3, 5, 9, 11, 13, 12, 14	NA
Exposure to air activation products	11, 14, 15	11, 14, 15	14, 15, 17
Exposure to ionizing radiation from sources other than accelerators	2, 3, 5, 9, 11, 12, 13, 14	NA	NA

Preventive and Mitigating Factors:

1. Alarm
2. Automatic Devices
3. Barriers/Isolation
4. Decontamination
5. Equipment Design/Aids
6. Fire Department
7. Insulation
8. Limited Quantities/Load
9. Lockouts/Interlocks
10. Manual Intervention
11. Monitoring
12. Personal Protective Equipment
13. Operational Procedures
14. Shielding
15. Ventilation
16. Emergency Plan
17. Dilution

NA Not Applicable

Preventive/Mitigating Features

All elements of the accelerator are enclosed in concrete shielding supplemented with lead and polyethylene in critical locations. Active radiation monitors in the experimental area with preset trip levels are part of the interlock chain. The administrative reporting level for site-boundary exposure is 10 mrem/year.

Consequences

Exposure at the site boundary to radiation from the shielded accelerators is not potentially lethal. Similarly, operation of the accelerator would have no major impact on the environment. From Table 4-4, it is judged that the consequence level at the site boundary of operating the accelerator is medium.

Table 4-4. Consequence Rating Levels.

Consequence Level	Description Words	Maximum Consequences
1	High	Serious impact on-site or off-site. May cause deaths or loss of facility/operation. Major impact on the environment.
2	Medium	Major impact on-site and/or minor impact off-site. May cause death, severe injury, or severe occupational illness to personnel or major damage to the facility/operation or minor impact on the environment. Capable of returning to operation.
3	Low	Minor impact on-site with no off-site impact. May cause minor injury or minor occupational illness, or minor impact on the environment.
4	Extremely Low	Will not result in a significant injury or occupational illness, or provide a significant impact on the environment.

Probability

Because the accelerator would neither be operated without shielding nor without the other preventive/mitigating factors enumerated, which are basic ingredients in the design of the ALS, the Technical Safety Subcommittee concluded that the probability of exposure to radiation at the site boundary was extremely low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of extremely low result in site-boundary exposure risk of negligible for both normal and abnormal operation of the accelerator.

Table 4-5. Probability Rating Levels.

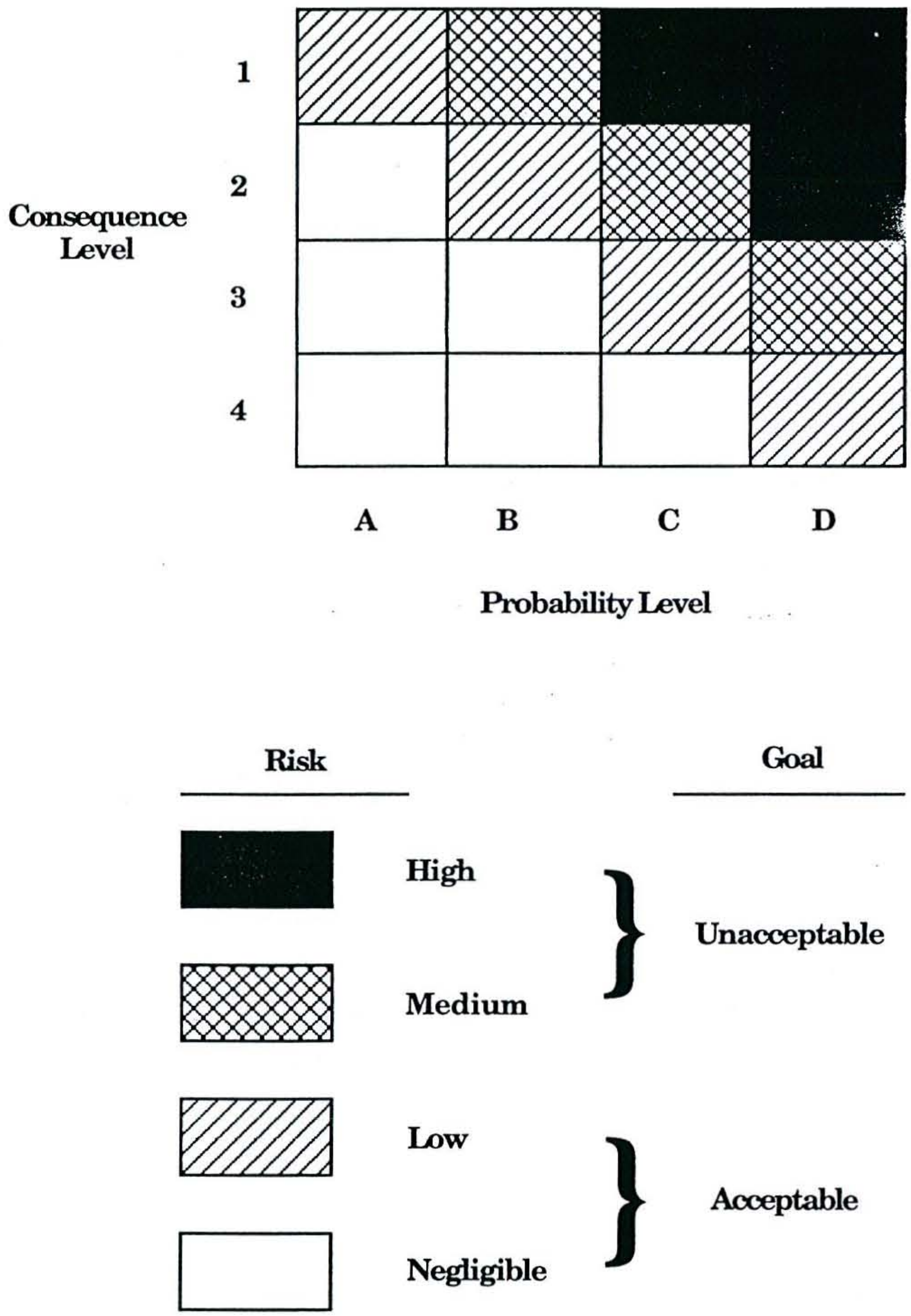
Category	Symbol	Description	Estimated Range of Probability of Accident Descriptive Word Occurrence per Year
Incredible		Probability of occurrence is so small that a reasonable scenario is not conceivable. These events are not considered in the design or FSAD accident analysis.	$<10^{-6}$
Extremely Low	A	Probability of occurrence is extremely unlikely or event is not expected to occur during the life of the facility or operation. Events are limiting faults considered in design (Design Basis Accidents).	10^{-6} to 10^{-4}
Low	B	Probability of occurrence is unlikely or event is not expected to occur during the life of the facility or operation.	10^{-4} to 10^{-2}
Medium	C	Event may occur during the facility or operation lifetime.	10^{-2} to 10^{-1}
High	D	Event is likely to occur several times during the facility or operation lifetime.	$>10^{-1}$

4.5.2 Hazard Event: Exposure to Ionizing Radiation outside Accelerator Enclosures

Initiating Occurrence

Occupational exposure to ionizing radiation may occur to workers in the ALS building under all operating conditions. Prompt radiation from operation of the accelerator systems comprises x-rays from the 120-kV electron gun and from rf power systems on the linac, booster, and storage ring, x-rays from the booster and storage-ring

Table 4-6. Risk Matrix.



rf cavities, and bremsstrahlung radiation and neutrons from the linac, booster, and storage-ring operation.

Method of Detection

Radiation is monitored by photon and neutron detectors at locations around the ALS facility. The monitors at fixed locations form part of the radiation safety system and are interlocked to trip the beam if limits are exceeded. There are also regular surveys made with portable monitors that are recorded in the radiation survey log book, as well as periodic surveys using thermoluminescent detectors to measure integrated doses over longer periods of time. Surveys are made at prescribed times and intervals. All personnel in the ALS building are required to wear personal dosimeters on the upper torso at all times.

Preventive/Mitigating Features

All elements of the accelerator are enclosed in concrete shielding supplemented with lead and polyethylene in critical locations. Access to the linac cave and the booster and storage-ring tunnels is prevented by fail-safe, redundant, independent interlocked physical barriers while the beam is on or the linac accelerator guides, the booster cavity, or the storage-ring cavity systems are rf-powered. Photon beamlines are designed to contain bremsstrahlung radiation within the vacuum chamber and are protected by lead shielding in critical locations. Active radiation monitors in the controlled areas with preset trip levels are part of the interlock chain. Interlocks are fail-safe, redundant, and testable. In addition, COPs and LSPs require that: (1) staff and visiting workers receive radiation safety training, (2) radiation surveys are made at prescribed times and intervals, (3) radiation detectors are calibrated at prescribed intervals, and (4) interlocks are tested as part of a scheduled maintenance program.

Consequences

Excess exposure to ionizing radiation may cause death, severe injury, or severe occupational illness to personnel. From Table 4-4, the consequence level is judged to be medium.

Probability

Excess exposure could occur if the shielding were improperly installed or if more than one radiation monitor malfunctioned in the same area. Radiation monitoring during one year of commissioning experience with linac and the booster has verified the adequacy of the linac and booster shielding design and installation. The adequacy of the storage-ring and beamline shielding appears assured based on calculations and extrapolation of injection-commissioning experience. The probability that more than one radiation monitor would fail simultaneously in the same area of the facility is low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level for exposure to excess ionizing radiation of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in risk of low.

4.5.3 Hazard Event: Exposure to Ionizing Radiation inside Accelerator Enclosures

Initiating Occurrence

Exposure to prompt radiation from operation of the accelerator systems could occur if a person were inside the accelerator enclosures while the accelerators were operating.

Method of Detection

Observation of affected personnel in the accelerator enclosures.

Preventive/Mitigating Features

Access to the linac cave and the booster and storage-ring tunnels is prevented by fail-safe, redundant, independent interlocked physical barriers while the beam is on or the linac accelerator guides, the booster cavity, or the storage-ring cavity systems are rf-powered. Before turning on the rf power systems or the accelerator beam, accelerator and controlled-area search and secure procedures are required. Audio and visual monitoring systems are active at all times in the gate areas. Interlocks are fail-safe, redundant, and testable. Warning lights/signs and audible alarms in the accelerator area are activated before these systems are turned on. Crash-off boxes are part of the interlock chain. Interlocks are tested as part of a scheduled maintenance program. Bypassing of interlocks is regulated by LBL procedures and specifically by a COP.

Consequences

Exposure to radiation from the unshielded accelerator is potentially lethal, but the consequences would be limited to the individual or few individuals inside the shielding. From Table 4-4, it is judged that the consequence level of exposure to ionizing radiation inside the accelerator enclosures is medium.

Probability

For an individual to be exposed to ionizing radiation inside the accelerator enclosures, several events would have to occur. First, either the search and secure procedure was not executed correctly, so that a person was inside an enclosure when the accelerator was turned on, or the interlock system would have to fail, so that a person could enter while the accelerator was turned on. Second, either the warning signs and lights and audible alarms would have to fail, the individual would have to disregard the signs and lights, or the crash-off boxes that are part of the interlock chain would have to fail. From experience at other accelerator facilities and from one-year ALS commissioning experience with the linac and the booster, it is judged that the probability of such events occurring is low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low for exposure to ionizing radiation inside the accelerator enclosure.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in risk of low.

4.5.4 Hazard Event: Exposure to Synchrotron Radiation

Initiating Occurrence

Exposure to synchrotron radiation can in principle occur for personnel in the beamline and experimental areas during operation of the accelerator.

Method of Detection

All personnel in the ALS building are required to wear personal dosimeters on the upper torso at all times.

Preventive/Mitigating Features

Beamlines are designed to contain the synchrotron radiation within the vacuum chamber. Access to beamline and experimental areas where exposure to synchrotron radiation could occur is prevented by interlocked physical barriers. Interlocks are fail-safe, redundant, and testable. COPs and LSPs require that (1) staff and visiting workers receive radiation safety training and (2) interlocks are tested as part of a scheduled maintenance program.

Consequences

Exposure to synchrotron radiation may cause injury or occupational illness to personnel. From Table 4-4, the consequence level is judged to be low.

Probability

Exposure to synchrotron radiation requires that the beamline and/or end station not be intact or that the protective interlock system fail when an attempt is made to pass through physical barriers blocking access. If the beamline were not intact, either the photon shutter and the personnel safety shutter in the beamline front end would be shut or storage-ring operation would be halted by the protective interlock system. If the end station were not intact, the end-station personnel safety shutter would be shut by the protective interlock system. Because of the fail-safe, redundant, testable character of the interlock system, the probability of any of these events is low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of low results in risk of negligible.

4.5.5 Hazard Event: Exposure to Air-Activation Products

Initiating Occurrence

Exposure to ionizing radiation can occur in the ALS building and at the site boundary as a result of the generation of air-activation products, primarily from photonuclear interaction of bremsstrahlung radiation with nitrogen-14 and oxygen-16 in the air around the accelerator to produce nitrogen-13 and oxygen-15, respectively.

Method of Detection

Regular monitoring for air-activation products will be carried out by the LBL Environment, Health, and Safety Division during the early operation of the ALS.

Preventive/Mitigating Features

The building enclosure affords mixing, dilution, and time delay, thereby reducing the exposure due to the short-lived isotopes produced at the ALS. In addition, fans and air-conditioning are installed and are required to be on during accelerator operations to minimize the concentration of activated air.

Consequences

Exposure to ionizing radiation from air-activation products may cause death, severe injury, or severe occupational illness to personnel. From Table 4-4, the consequence level is judged to be medium.

Probability

The primary protective mechanism (the building itself) is passive and cannot fail. The secondary protective mechanism (the fans and air conditioning) are required to be operating before the storage ring is turned on. The probability of the hazard event is therefore extremely low, and, from Table 4-5, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of extremely low results in risk of negligible.

4.5.6 Hazard Event: Exposure to Ionizing Radiation from Sources other than Accelerators

Initiating Occurrence

Exposure to ionizing radiation can occur due to production of low-energy x-rays in components of the rf power systems, including the klystrons, vacuum switches, and modulator tetrodes.

Method of Detection

X-rays are detected by routine area monitoring and by personnel dosimetry.

Preventive/Mitigating Features

The rf power systems are commercial equipment of the type that has been installed elsewhere for many years at accelerator facilities and such industrial plants as television stations. The klystrons are shielded. The glass vacuum switches are in interlocked enclosures by three separate safety systems. The tetrode modulator is contained with an aluminum deck and the deck is further enclosed by a steel equipment cabinet. COPs cover all aspects of operation, testing, maintenance, and repairs. Film badges and calibrated x-ray monitors will be required. Physical barriers will prevent access.

Consequences

Exposure to ionizing radiation may cause severe injury, or severe occupational illness to personnel. From Table 4-4, the consequence level is judged to be medium.

Probability

Exposure to x-rays will require failure of interlocked enclosures, failure of x-ray monitors, and/or failure to follow administrative procedures. The probability of the hazard event is low, and, from Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in risk of low.

4.6 Conclusions

Operations activities planned for the ALS facility have been analyzed for ionizing-radiation hazard potential, and appropriate mitigation measures have been developed. The hazards analysis identified potentially hazardous conditions that could occur in the ALS during operations. Control measures were incorporated into the facility and systems design to mitigate most of the identified potential hazards. In other cases, administrative procedures were developed to ensure that facility operations could be conducted with a minimum of on-site and off-site consequences.

A risk analysis based on credible ionizing-radiation hazard events, performed using a bounding event/worst-case approach, showed that the ALS facility will be operated within the risk envelope for low-hazard facilities as defined in SAN Management Directive 5481.1A. Table 4-7 summarizes the risk analysis.

Table 4-7. ALS Ionizing Radiation Risk-Determination Summary.

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
	Ionizing Radiation			
1	Exposure to Ionizing Radiation at the Site Boundary	Extremely Low	Medium	Negligible
2	Exposure to Ionizing Radiation outside the Accelerator Enclosures	Low	Medium	Low
3	Exposure to Ionizing Radiation inside the Accelerator Enclosures	Low	Medium	Low
4	Exposure to Synchrotron Radiation	Low	Low	Negligible
5	Exposure to Air Activation Products	Extremely Low	Medium	Negligible
6	Exposure to Ionizing Radiation from Sources Other than Accelerators	Low	Medium	Low

SECTION 5. SAFETY ANALYSIS—OTHER THAN IONIZING RADIATION

The ALS safety analysis was prepared in accordance with the guidance provided in DOE Order 5481.1B, Safety Analysis and Review System [DOE, 1986a]. A description of the methodology used in identifying hazards, analyzing credible accident scenarios, and assessing risks is presented in Section 5.1. The hazards are identified in Section 5.2, except for ionizing radiation hazards, which are discussed in Section 4. The sections following Section 5.2 contain safety analyses for the hazards. Conclusions and an assessment of the overall risk associated with ALS operations are discussed in Section 5.10.

5.1 Safety Analysis Methodology

The methodology used to perform the ALS safety analysis is shown in Figure 4-1 (page 4-02). The hazards analysis process began with a review of proposed ALS commissioning, operations, and research activities. Information concerning operations and research at similar facilities at other laboratories was also reviewed. Using the information obtained, a hazard analysis of proposed ALS activities was prepared. Potential hazards associated with the use of energy sources, hazardous materials, and from natural phenomena were studied.

Credible hazards with potential on-site or off-site consequences were then analyzed to assess associated risk. The analyses were based on a bounding event approach, where the most severe of each particular category of credible accident was analyzed to obtain worst-case results . Each event analysis included determining the initiating occurrence, possible detection methods, the safety features that might have prevented or mitigated the event, the probability of the event occurring, and the possible consequences.

The probability estimates were made by the Technical Safety Subcommittee of the ALS EH&S Committee on the basis of the best professional judgement of the members of the subcommittee. The judgements were supported by statistics on occurrences at DOE accelerator facilities for the period September 1990 to December 1992 obtained through the DOE Occurrence Reporting and Processing System (ORPS) [DOE, 1993] and by data accumulated on actual instances of exposure to radiation at LBL over the period 1981-

1986 [EH&S, 1987]. In addition, site-specific design criteria for earthquakes were used in determining the probability of these events [UCRL, 1989].

Using the guidance provided in SAN Management Directive 5481.1A [SF, 1989] for conducting safety analyses, the probability and consequences of each hazard were rated by levels. Table 4-4 (page 4-44) summarizes the consequence levels, and Table 4-5 (page 4-45) summarizes the probability levels, as provided by SAN MD 5481.1A.

The overall risk associated with each specific hazard, and then for the facility as a whole, was determined using these rating levels and the risk matrix (Table 4-6 on page 4-46) also provided in SAN MD 5481.1A.

5.2 Hazard Control Matrix

Credible hazards were identified in 19 categories, as summarized in the hazards control matrix below (Table 5-1), which correlates the hazard category with locations in the ALS facility where that hazard exists:

The following sections comprise the safety analyses for hazards other than ionizing-radiation, according to the methodology outlined in Section 5.1. Ionizing-radiation hazards are analyzed in Section 4.

5.3 Fire Safety

The ALS building was designed and contracted for under the 1985 editions of the Uniform Building Code [UBC, 1985] and the Life Safety Code [NFPA, 1985]. DOE Orders 5480.7, Fire Protection [DOE, 1987b], and 6430.1A, General Design Criteria [DOE, 1987a], were also enforced. Other observed guides and standards come from the Factory Mutual Engineering Corporation, Underwriters Laboratories, and the Office of the State Fire Marshal.

5.3.1 Building Construction

The ALS building is a two-story building with a total floor area of 114,000 gross square feet (gsf). The building consists of:

Table 5-1. Hazard Control Matrix

Hazard Type	Accelerator Area	Experimental Floor	Site Boundary
Room fire	1, 2, 3, 6, 8, 10, 11, 13, 15	1, 2, 3, 6, 8, 10, 11, 13, 15	16
Room fire with radioactive or toxic materials	1, 2, 3, 6, 8, 10, 11, 13, 15	1, 2, 3, 6, 8, 10, 11, 13, 15	11, 16
Equipment fire	1, 2, 3, 6, 8, 10, 11, 13, 15	1, 2, 3, 6, 8, 10, 11, 13, 15	NA
Uncontrolled chemical reactions	1, 5, 6, 8, 10, 11, 12, 13, 15	1, 5, 6, 8, 10, 11, 12, 13, 15	NA
Chemical exposure	1, 5, 6, 8, 10, 11, 12, 13, 15	1, 5, 6, 8, 10, 11, 12, 13, 15	NA
Cryogenic temperature exposure	5, 8, 10, 12, 13	5, 8, 10, 12, 13	NA
Compressed-gas explosion	1, 5, 6, 8, 10, 11, 12, 13, 15	1, 2, 5, 6, 8, 10, 11, 12, 13, 15	NA
Gas explosion (hydrogen, oxygen, acetylene)	5, 6, 8, 10, 12, 13, 15	5, 6, 8, 10, 12, 13, 15	NA
Inhalation, ingestion, or dermal exposure to toxic or carcinogenic material	5, 6, 8, 10, 12, 13, 15	5, 6, 8, 10, 12, 13, 15	11, 16, 17
Oxygen-deficient atmosphere	1, 11, 13, 15	1, 11, 13, 15	NA
Electrical shock	2, 3, 5, 7, 9, 10, 11, 13	2, 3, 5, 7, 9, 10, 11, 13	NA
High magnetic forces	3, 9, 11, 13, 14	3, 9, 11, 13, 14	NA
Nonionizing-radiation	2, 3, 5, 9, 10, 11, 13	2, 3, 5, 9, 10, 11, 13	NA
Laser-light energy transfer	NA	3, 5, 9, 10, 11, 12, 13	NA
Exposure to visible or near-UV light	NA	3, 5, 10, 13	NA
Ozone	3, 11, 13, 15	3, 11, 13, 15	NA
Earthquake	5, 13, 16	5, 13, 16	16
Beamline vacuum vessel implosion or explosion	NA	5, 13	NA
Rotating machinery and falling objects	3, 5, 9, 13	3, 5, 9, 13	NA

Preventive and Mitigating Factors:

1. Alarm
2. Automatic Devices
3. Barriers/Isolation
4. Decontamination
5. Equipment Design/Aids
6. Fire Department
7. Insulation
8. Limited Quantities/Load
9. Lockouts/Interlocks
10. Manual Intervention
11. Monitoring
12. Personal Protective Equipment
13. Operational Procedures
14. Shielding
15. Ventilation
16. Emergency Plan
17. Dilution

NA Not Applicable

- The original one-story 184-Inch Cyclotron building (which will be referred to as the original building) , a 24-sided, essentially circular structure about 163 feet in diameter with a domed roof 65 feet high at the apex. The floor area is 20,800 gsf.

- A new two-story addition that is approximately concentric to the original building. The addition has a flat roof 87 feet wide and 30 feet high. The total floor area is 93,000 gsf, of which 60,200 gsf is on the first floor and 33,000 gsf is on the partial second floor.

The original building was completed in 1942. It received a substantial addition in 1961, which has since been removed as part of the ALS project. The original drum-shaped sides are about 49 feet high, thereby extending 19 feet above the new addition. The structural steel frame consists of columns and curved trusses that support the domed roof, which is sheathed with heavy-timber tongue-and-groove decking.

Modifications to the original building include the removal of all existing utilities, services, and combustible materials and replacement with systems and materials conforming to applicable codes. Light-wood framing, which formed the circumferential parapet was removed and replaced with steel framing. The heavy-timber roof decking that forms the dome remains. The magnet yoke also remains.

The new addition is constructed of structural steel with one-hour fireproofing. To maintain a seismic flexible separation, the building is not structurally attached to any adjacent buildings. The partial second floor, located completely within the new addition is separated from the first floor by one-hour fire-resistive construction. There is no separation at the first-floor level between the original building and the new addition.

The addition is built on new concrete footings, along with a heavy-duty concrete floor slab. The roof consists of ribbed metal decking on a steel frame, supported by steel beams and columns, and finished with a single-ply roof over rigid thermal insulation. Exterior walls are sheathed with vertically-ribbed, thermally insulated metal siding and cementitious panels extending from the concrete floor to the top of the parapet, to replicate and replace the corrugated transite panels of the original building. Roll-up doors are provided for vehicle access to the experimental areas and the support facilities. The floor contains no drains and is coated with an epoxy sealer, both features helping to prevent environmental contamination.

The structural steel support columns of the new addition were located so that the 30-ton bridge crane (with 5-ton auxiliary) that was in an annex of Building 6 could be reinstalled. The reinstalled bridge crane services the full circumference of the ALS storage ring. The linear accelerator and booster synchrotron are serviced by the original 30-ton polar crane operating in the domed area of the original building.

Buildings 10 and 80 immediately adjacent to the ALS have been modified only to the extent of window and door removals and their replacement with matching fire-rated wall materials where they are common with the new-addition walls. There is a seismic gap between the ALS and these buildings. Dedicated to support of ALS activities, Building 80 is included in this FSAD.

The Building 6 area is surrounded on three sides by roadways and service-vehicle parking. Roadways around the site have been improved and some close-in parking has been provided.

5.3.2 Fire Protection Systems

Fire protection in the ALS is governed by applicable codes and standards, including chapter 12 of the LBL Health and Safety Manual [LBL, 1992a]. The LBL Fire Department reviewed and approved the fire-protection systems for the ALS. Locations of fire-protection systems are specified in the ALS Pre-Fire Plan prepared by the Fire Department [Fire Department, 1992] and in the Building 6 Complex Emergency Plan [EH&S, 1992]. The Emergency Plan includes the ALS building (Building 6), Building 80, and Building 10.

Fire protection features include:

- LBL Fire Department.

The LBL Fire Department station is located within 200 feet of the ALS building, is staffed continuously, normally by five paid career firefighters. The Fire Department will provide on-scene response within three minutes of any alarm. Normal first-alarm response is with two pumper engines with total rated capacity of 2250 gallons per minute. There are also a brushrig, a 2000-gallon water tanker, and an ambulance. In addition, engine and ladder service and fire fighters are available on call via LBL fire dispatch direct line or radio channel from the Berkeley Fire Department on the second alarm and the Oakland Fire Department on the third alarm. Berkeley and Oakland border LBL.

- Water supply for fire protection.

The fire hydrants, automatic sprinkler systems, and inside fire-hose stations in the ALS building are supplied by an 8-inch water-main loop around the building. Water is supplied by the LBL site-wide, looped and gridded distribution system of mainly 8-inch and 12-inch mains. The 8-inch loop around the ALS building is fed at three points by the site-wide system.

The public utility reservoirs that feed the site-wide system are supplemented by two widely separate on-site storage tanks, each of 200,000 gallons capacity. These tanks supply two separate sets of automatic-starting diesel-engine-driven fire pumps.

Flow tests show that the available water quantities and pressures are adequate for automatic sprinkler systems and inside hose stations [Plant Engr, 1992, Appendix A-11].

- A wet-pipe, automatic fire-sprinkler system throughout the building.

All of the ALS facilities are protected by wet-pipe sprinkler systems meeting DOE standards and all related regulations. There are nine sprinkler zones, including the second-floor area, accelerator tunnels, and underground cable vaults. The first zone covers the original building beneath the dome roof, which earlier had a pre-action dry system, and now has a wet sprinkler system providing Ordinary Hazard, Group 2 protection. The building addition with new structural steel protected to 1 hour is sprinklered throughout and consists of three zones each on the first floor and second floor, providing Ordinary Hazard, Group 3 protection. The accelerator tunnels are protected to the equivalent of Ordinary Hazard, Group 2. Experimental stations in the experimental hall will be individually sprinklered.

The 12-kV electrical substation is located 25 feet from the ALS building. Pit and tunnel areas are protected with sprinklers to Ordinary Hazard, Group 2. This protection level exceeds Pacific Gas & Electric standards and meets Factory Mutual Engineering Corporation criteria for Improved Risk.

- Smoke detection systems.

An ionization-type smoke detector system is installed throughout the ALS building. The main floor comprises three smoke detection zones corresponding to the areas served by the three 50,000 cfm roof exhaust fans. Ionization-type detectors are also located in the shielding-tunnel exhaust-fan ducts and ventilation-system ducts. In addition, a fourth zone in the southwest sector (adjacent to Building 10) with a 20,000 cfm dedicated smoke purge fan will utilize space-type ionization smoke detectors.

- A smoke-purging system designed to actuate automatically upon detector activation.

The smoke-purge system includes automatic and manual activation of the four major exhaust fans on the main floor. These fans will exhaust the affected area(s) and pressurize surrounding areas. There are separate smoke-control systems for the linac cave, the booster synchrotron, and the storage ring.

Twelve barometric dampers, each 42 square feet in area, are installed around the base of the dome and rise above the roof of the new addition. These dampers open out with building positive pressure caused by fire and will assist in venting of smoke.

- Isolation of the future second-floor HVAC system.

The HVAC system for the second floor is completely isolated from that of the main floor and automatic shutdown of second-floor supply air takes place if ionization-type smoke detectors in second-floor supply ducts activate.

- Audible local alarm systems in the entire building.

The alarms are activated from both suppression and detection systems. The nine sprinkler zones will be monitored by sprinkler water-flow detection and control valve supervisory switches throughout the building. There are 14 manual pull fire alarm stations at exit points on the main floor. Laboratory areas of the second floor (when completed) will be equipped with space-type smoke detectors.

The alarm system will be fully addressable, allowing for documentation and rapid location of specific initiating devices. Zone alarm signals will be transmitted directly to the LBL Fire Department, thus minimizing response time.

- Fire hydrants, fire hose and fire extinguishers.

Four fire hydrants on the south, east, west, and north sides of the ALS building are available. There is a sprinkler connection at the location of the south fire hydrant.

Six fire-hose stations with 1-1/2 inch hoses are provided, primarily for occupant use, in strategic locations in substantial conformance with NFPA Standard No. 14. The hoses are supplied from the automatic sprinkler systems.

Twenty five halon fire extinguishers are installed through the main floor of the building in accordance with NFPA Standard No. 10. Experimental stations in the experimental hall will be similarly equipped. Fire extinguishers on the second floor are to be determined.

- Dry standpipes.

Three dry standpipes conforming to NFPA Standard No. 14 are provided with duplex connections on the main floor, the second floor, and on the roof with Fire Department hose connections at strategic locations outside the building to expedite fire attack. The system water is supplied by Fire Department pumpers from the site fire hydrants. Dry standpipes are located at the building lobby between sectors 12 and 13 (north side) and the roll-up doors between bays 3 and 4 (southeast corner) 19 and 20 (southwest corner between Building 10 and 80) and to maximize their accessibility to nearby fire hydrants.

Figures 5-1 and 5-2 show the locations of the fire-hose stations, fire extinguishers, dry standpipes and other emergency equipment in and around the ALS building.

5.3.3 UBC Building Occupancy Classification and Maximum Allowable Area

The UBC occupancy and construction-type designation for the ALS building is B-2 Occupancy and Type II one-hour construction. Determination of this designation was based on UBC provisions for historical buildings and on the requirements established by the University of California Board of Regents for preservation of internal and external architectural features of the original building [Plant Engr, 1992]. The mitigation measures incorporated to preserve the historical and architectural significance of the original building constitute legal requirements for design and construction of the ALS, thereby providing a firm basis for application of the UBC provisions for historic buildings. In particular, not fireproofing the structural steel members in the original building and retention of the heavy-timber roof decking in the dome of the original building were necessary to meet the requirements for preservation of the internal architectural features.

The building area is based on the designation of B-2, Type II one-hour and on credits for having (1) two stories, (2) fully sprinklered fire protection system, and (3) side-yard separations sufficient to permit an area increase of 1.6. Under these conditions, the allowable total area for the two-story ALS building is 115,200 square feet, as compared to the design area of 114,000 square feet, and the allowable area for any one floor is 86,400 square feet, as compared to the design area of 81,000 square feet

Two determinations made by the LBL Building Official support this maximum allowable area:

(1) Determination of the construction type as one-hour even though the structural steel members in the original building are not fireproofed and the roof decking in the dome is heavy timber, and

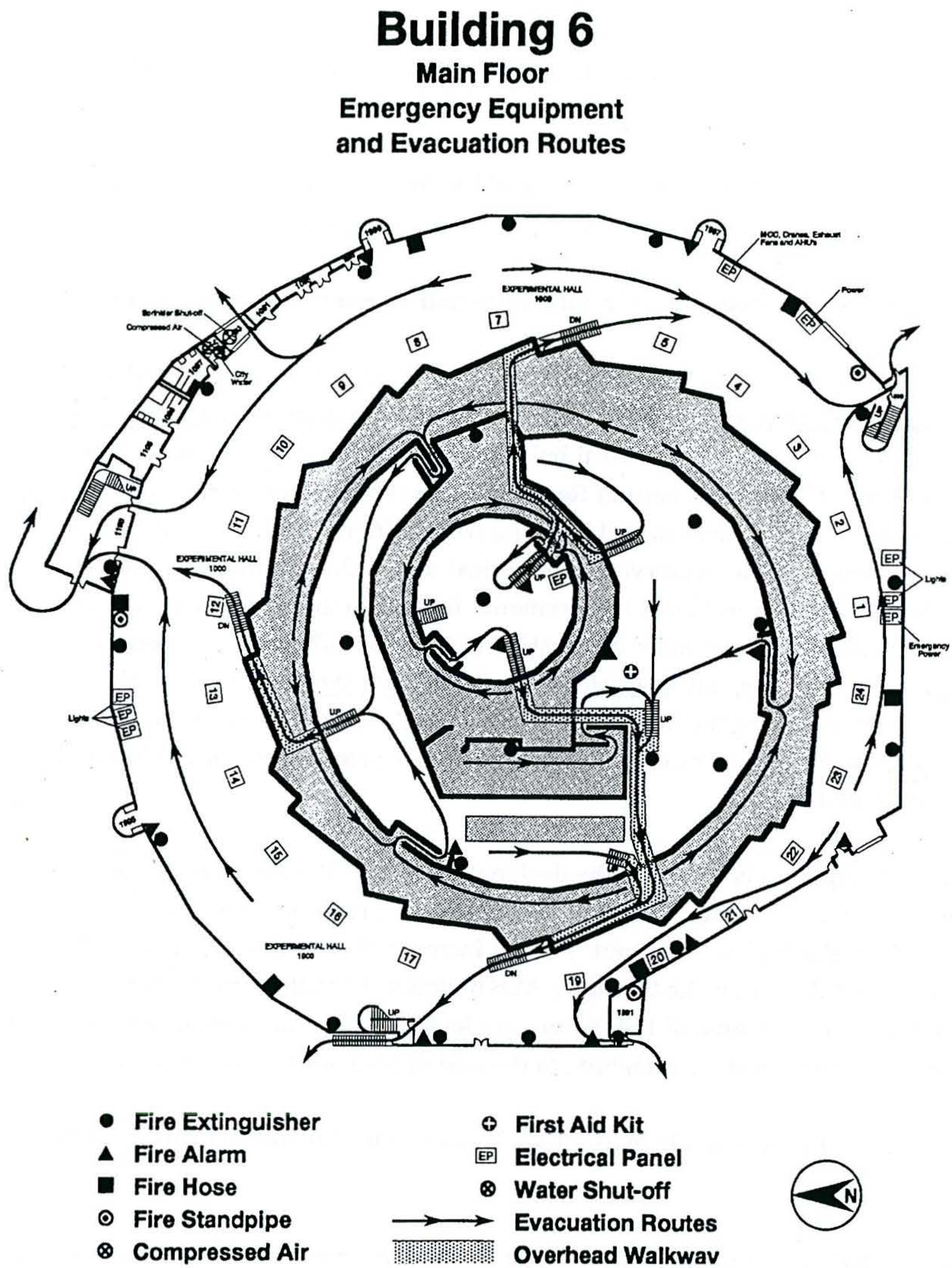


Figure 5-1. Location of emergency equipment and evacuation routes in the ALS building.

Building 6 Complex

Emergency Evacuation Routes and Assembly Areas

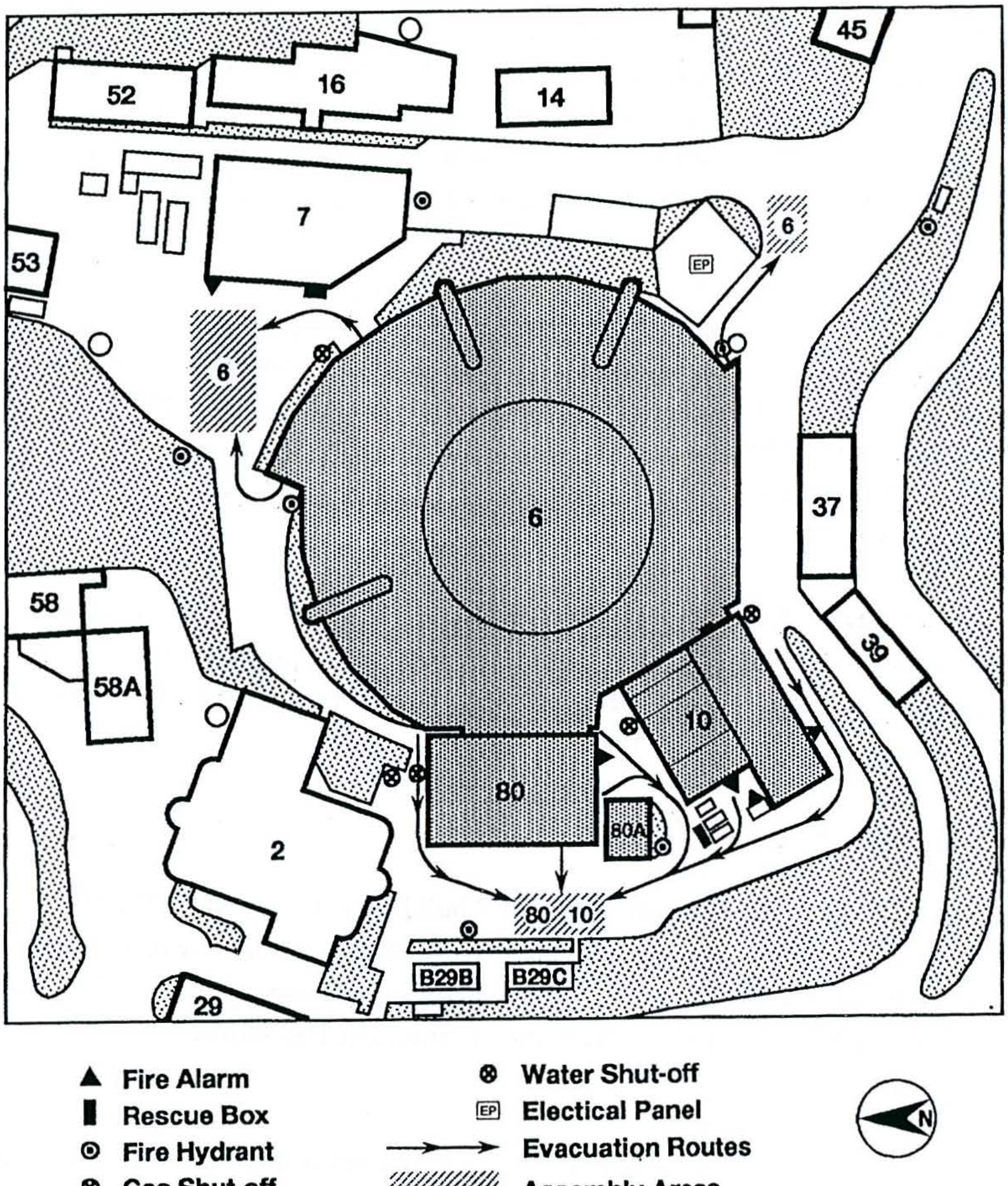


Figure 5-2. Location of emergency equipment, evacuation routes, and assembly areas in the ALS building area.

(2) Determination that the side-yard separation is 1.6 minimum.

Both determinations are based on meeting the intent of the code rather than its prescriptive requirements. The UBC gives the Building Official side authority to use intent as a basis for additions , alterations, or repairs of existing buildings without complying with all prescriptive provisions of the code, as long as the new work will not make the exiting building more hazardous than it was. In particular, Section 106 [UBC, 1988] permits the Building Official to modify the requirements of the code if strict application is impractical and the modifications are in conformance with the intent and purpose of the code.

The LBL Plant Engineering Department has analyzed both determinations in the light of these considerations [Plant Engr., 1992]. The conclusions are that (a) the designation Type II one-hour constructions is reasonable and fulfills the intent of the code and (b) the ALS building has separations equivalent to a rectangular building with side yards on three sides of at least 50 feet, providing an allowable area increase factor greater than 1.6.

The DOE Office of Assessment and Support has also reviewed these issues and concurs that fireproofing the structural steel in the original building is not required and that there is adequate side-yard separation to allow personnel egress and fire-department access [Maher, 1992].

5.3.4 Life Safety Analysis

Life Safety requirements of the ALS building were based on NFPA Standard No. 101 Life Safety Code for an industrial facility primarily occupied by equipment with a relatively low density of people and low to ordinary hazard. A life safety code analysis has been carried out by the LBL Plant Engineering Department [Plant Engr., 1992, Appendix A-1].

For purposes of the life safety analysis, the main floor of the ALS building comprises two areas. The first is the 40,000-square foot accelerator area, which extends from the center of the original building to the storage-ring outer shielding wall in the new addition. The second is the remainder of the new addition, which includes the beamline and experimental areas outside the storage-ring shielding. It should be noted that the smoke-removal system, which is provided in the ALS building to enhance life safety for occupant egress and fire-fighting capability, is not required for low-to-ordinary hazard special-purpose industrial occupancies to meet the exiting provisions of the Life Safety Code. There are also emergency lighting and emergency notification (PA) systems.

The accelerator area consists of the storage-ring tunnel, the north and south open areas bounded by the storage ring , the booster-ring tunnel, the linac cave, and the open area bounded by the booster ring.

When the accelerator is in operation, there will be no more than two employees in the open area bounded by the booster-ring tunnel, and no one will be inside the accelerator enclosures. When the accelerator is shut down for maintenance, the occupant load will not be more than 15 employees. On rare occasions, a small group not to exceed 10 persons will be in this area for a guided tour. The probable maximum occupant load will not exceed 30 persons at any time.

Exiting arrangements are shown in Figure 5-1. There are at least two exits provided from each area except the linac cave, which has only one approved means of egress.

The exiting passageways are 36-inch wide areas bounded by stripes painted on the floor. Directional arrows are also painted on the floor within the striped paths. There is also signage indicating the direction to the nearest exit at intersections where more than one direction of travel are available. The directional arrows on the floor and the nearest exit directional signage are in addition to the exit signage as required by the Life Safety Code. There will also be occupant load signs indicating that no more than 30 persons are permitted in the accelerator area. Such signs will be posted at all accelerator-area entrances.

Two sets of stairs are provided for access to the roof of the booster-ring tunnel and the storage-ring tunnel from each open area. Three sets of stairs are provided from the roof of the storage-ring tunnel to the experimental hall for exiting the building. All stairs are 36 inches wide. Two of the stairs are fire-escape stairs and are located inside the open spaces bounded by the storage-ring tunnel, one in the north open space and one in the south open space. Each of these open spaces has another stair as the primary means of egress.

In the experimental hall, it is anticipated that usage and equipment arrangement will vary greatly over the years. An occupant load factor of 100 square feet per person was used in the life safety code analysis. The probable maximum occupant load is 410 persons.

Total occupant load for the main floor is 440 persons maximum (410 in the experimental hall and 30 in the accelerator area.

The area of the future ALS second floor is 33,000 square feet. The proposed usage is primarily offices for visiting researchers, light laboratories, two mechanical rooms, and a boiler room. Usage and floor layouts have not been finalized. For the life safety code analysis, an occupant load factor of 100 square feet per person is used, giving a calculated occupant load of 330 persons. Three enclosed stairwells are provided and located at least 192 feet apart.

Table 5-2 shows the exiting requirements and the actual conditions for the main floor [Plant Engr., 1992]. The maximum travel distance from any point on the main floor to an exit is 400 feet, in conformance with the Life Safety Code. The floor exiting arrangement conforms to the Life Safety Code with two exceptions:

- The linac cave has one approved exit, thereby creating a common path of travel of 120 feet. The life safety code analysis concludes that, considering the low hazard level and the fire-protection features in the cave, the 120-foot maximum common path of travel will not jeopardize the life-safety aspects of the building.

- The fire-escape stairs are located in areas congested with equipment and building structural components. The life safety code analysis concludes that, based on the maximum occupant load of 30, use of the fire-escape stairs provides adequate exiting and does not pose a life-safety hazard to the occupants.

Table 5-2. Life Safety Code Analysis of the ALS Building.

MAIN FLOOR

Occupancy Classification	Special Purpose Industrial	
Hazard	Ordinary	
Accelerator Area	.	
Area	40,000 sq. ft	
Occupant Load Factor	Maximum Probable Employees and Occasional Guests	
Occupant Load		
Inside Storage-Ring Tunnel	Total of 30 Persons Maximum in All Five Areas	
Open Area within Storage Ring		
Inside Booster Tunnel		
Open Area within Booster Ring		
Inside Linac Cave		
Number of Exits Required/Provided		
Inside Storage-Ring Tunnel	2/2	
Open Area within Storage Ring	2/3	
Inside Booster Tunnel	2/2	
Open Area within Booster Ring	2/2	
Inside Linac Cave	2/1	**See Justification**
Exit Width		
Inside Storage-Ring Tunnel	2 @ 36 Inches Each	
Open Area within Storage Ring	2 @ 36 Inches Each	
Inside Booster Tunnel	2 @ 36 Inches Each	
Open Area within Booster Ring	2 @ 36 Inches Each	
Inside Linac Cave	2 @ 36 Inches Each	
Allowable Exit Travel Distance to Exterior or Horizontal Exit in Sprinklered Building	400 Feet Maximum	
Actual Exit Travel Distance		
Inside Storage-Ring Tunnel		
From Point I to Exit E	392 Feet	
From Point I to Exit C	400 Feet	
From Point II to Exit E	394 Feet	
From Point II to Exit C	362 Feet	
Open Area within Storage Ring/Southern Sector		
From Point III to Exit E	299 Feet	
From Point III to Exit B	251 Feet	
Open Area within Storage Ring/Northern Sector		
From Point IV to Exit E	218 Feet	
From Point IV to Exit C	204 Feet	
Inside Booster Tunnel		
From Point VI to Exit E	398 Feet	
From Point VI to Exit B	393 Feet	
Open Area with Booster Ring		
From Point VII to Exit B	337 Feet	
From Point VII to Exit E	325 Feet	
Inside Linac Cave		
From Point V to Exit E via Linac	312 Feet	
Common Path of Travel	120 Feet > 50 Feet Allowed	**See Justification**
Existing Dead End Pocket	120 Feet > 50 Feet Allowed	**See Justification**

Table 5-2. Life Safety Code Analysis of the ALS Building (cont.).

Experimental Hall	
Area	41,000 Square Feet
Occupant Load Factor	100 Square Feet per Person
Occupant Load	410
Number of Required Exits	2 for Occupant Load of 440 (410 + 30)
Number of Exits Provided	5
Exit Width Required	88 Inches (0.2 Inches × 440 = 88 Inches)
Exit Width Provided	252 Inches with 36-Inch Minimum Width
Travel Distance Allowed	400 Feet
Travel Distance Provided	270 Feet Maximum
Exit Separation Required	142 Feet (Half the Diagonal Distance)
Exit Separation Provided	192 Feet Minimum
SECOND FLOOR	
Occupancy Classification	Business
Hazard	Ordinary
Area	33,000 Square Feet
Occupant Load Factor	100 Square Feet per Person
Occupant Load	330 Persons
Number of Required Exits	2 for Occupant Load of 330
Number of Exits Provided	3
Exit Width Required (Level Components)	66 Inches (0.2 Inches × 330 = 66 Inches)
Exit Width Provided (Level Components)	144 Inches with Three at 36 Inches Minimum Width
Exit Width Required (Stairs)	99 Inches (0.3 Inches × 330 = 99 Inches
Exit Width Provided (Stairs	144 Inches with Three at 48 Inches Wide Each
Travel Distance Allowed	400 Feet
Travel Distance Provided	270 Feet Maximum
Exit Separation Required	142 Feet (Half the Diagonal Distance
Exit Separation Provided	192 Feet Minimum

5.3.5 Fire Loss Potential

The initial value of the completed ALS facility at the beginning of operations in 1993 will be approximately $80 million (1990 dollars). The value will increase as more beamlines and experimental stations are added. After five years of operations, the value will be approximately $120 million (1990 dollars). The maximum possible property loss in the event of a fire on the main floor is estimated to be in excess of $75 million [Plant Engr., 1992, Appendix A-11]. The main floor comprises an open area of some 81,000 square feet.

DOE Order 5480.7 Fire Protection states that when the maximum possible property loss exceeds $50 million, redundant fire-protection systems are to be provided and that, to limit the maximum property loss to $75 million, a failure-proof fire-protection system, such as blank walls or physical separation, is to be provided.

To meet the literal requirements of DOE Order 5480.7 would require the installation of four-hour fire-separation walls, thereby subdividing the ALS building into isolated zones. However, installation of such walls is not practical. The areas interior to the storage ring must remain open to accommodate the use of the polar crane in the original building and the bridge crane in the new addition. In addition, fire walls could not be built around or through shielding tunnels. To build around a shielding wall would severely compromise the integrity of the fire wall, while to build through a tunnel would disable the accelerator. These areas alone contain equipment with a replacement value in excess of $60 million.

The only area on the main floor subject to subdivision by fire walls would be the area of the experimental hall directly below the second floor. This area could be subdivided by free-standing four-hour fire walls. The fire walls would be required to extend from floor to parapet, three feet above the roof. Installation of such fire walls could reduce the maximum possible loss to less than $75 million. Such a subdivision would not protect the full length of the synchrotron-radiation beamlines, and each beamline would have to penetrate a fire wall, compromising fire-wall integrity. Fire walls would also make installation, operation, and servicing of beamlines difficult and costly and would introduce substantial emergency egress difficulties.

Because four-hour firewall separations are not feasible, a waiver of the $75 million fire-loss requirement was requested to allow the construction of the ALS facility with the open configuration described in Section 5.3.1. The waiver request was also based in part on the many fire-protection features described in Section 5.3.2, such as redundant water reservoirs, conservative wet-sprinkler system design, smoke detection and alarm systems, standpipes, additional fire-hose stations, and fire department location within 200 feet of the ALS building. The DOE has approved the waiver request [Ziemer, 1990].

5.3.6 Description of Fire Hazard

The primary fire hazard is in the original building because of the heavy-timber roof deck in the dome and the unfireproofed structural steel members. However, even in this area, the fuel loading is minimal. Dry-type transformers and electrical panels are located next to the unprotected steel columns. In addition. UL-listed power and control cables with low flame-spread characteristic jackets are laid in trays that are attached to the columns and control panels. All of these will burn only if constant ignition and heat sources are available. If not, they will not sustain burning, owing to the limited quantity of combustible contents in the equipment and components.

The potential fuel sources for fire are (1) the two 100-gallon-capacity transformers located outside the booster ring, (2) the five-gallon-capacity oil-filled transformer located next to two of the steel columns, and (3) wooden pallets for equipment delivery.

The oil used in the 100-gallon-capacity transformers has a flash point of 148°C. The operating characteristic of this transformer dissipates 1250 watts, which is very low in comparison to typical transformers of 30 kilowatts and above. Each transformer is installed over a drip pan that has a containment capacity of approximately 20 gallons with a 1-inch gravity drain line for transporting any leakage into a 120-gallon-capacity steel tank located in a below-grade trench. The fire hazard potential of these units is very low since the unit will shut down automatically if there is a loss of six gallons or more, and the spill will be confined to the drip pan and the below-grade holding tank.

The 5-gallon-capacity transformers pose very little threat to the steel columns [Plant Engr., 1992, Appendix A-2]. In the event of a transformer rupture (assuming the liquid spilled over an area approximately 6 feet in diameter with a liquid depth of 1/4 inch), the total heat release will be approximately 630,000 Btu in two minutes . Considering the present location of the transformer, it is unlikely that a liquid spill would completely surround the column on all sides. The amount of heat absorbed is only a fraction of the total heat released by the fire. Neither the heat release nor the duration is near the limit that can raise the temperature of the steel to its critical point. The available fuel load would be spent before the temperature of the column could rise to a damaging level.

It is possible for equipment to be delivered with wood pallets or crating inside the area surrounded by the storage ring. The chance of having any of the pallets located next to the unprotected steel columns is remote. Through strict administrative control, the storage of pallets in this area can be eliminated with all pallets being removed once the equipment is off-loaded.

The most serious fire hazard in the experimental area, which is fully fireproofed and sprinklered, is likely to come from flammable liquids and gases brought by ALS users. At this time, it is not possible to list specific materials or their amounts. In general, flammable liquids and gases will be stored in UL approved metal fire-storage cabinets. Amounts will be limited according to the Uniform Fire Code [UFC, 1988]. There will be gas detection devices in areas containing flammable gases. Because of the limited quantities of these materials, the fire potential is low. Further discussion of hazardous materials is found in Section 5.4.

5.3.7 Exposure Fire Potential

Exposure is the potential for heat to be transmitted from one building to another, with radiation as the primary means of heat transfer. Uniform Building Code provisions are based on the assumption that the owner can have no control over the type of construction and fuel loading that exists on adjacent property nor over what activities occur there. Consequently, the locations of buildings must be regulated relative to their distance from adjacent buildings and property lines. This concept provides a convenient and prescriptive means of protecting one building from another, insofar as fire exposure is concerned.

The space between the periphery of the ALS building and other nearby buildings provides protections against exposure by thermal radiation. The building has no significant exposure from other buildings less than 50 feet away over approximately 85% of its circumference. Buildings 10 and 80, which are included in this 85%, abut the ALS building, are separated by two-hour fire-resistive construction. Building 7, which is separated from the ALS building by approximately 20 feet, occupies 11% of the circumference. However, Building 7 is scheduled for removal in FY 1993. When Building 7 is removed, there will be no significant fire exposure to the ALS building from other buildings less than 50 feet away over 96% of its circumference. Only the switch-gear house remains. Operational plans for fire fighting include considerations for the temporary existence of Building 7.

5.3.8 Administrative Controls

A host of administrative controls are described elsewhere in this FSAD, primarily in Section 4, that bear on fire safety. Adherence to Chapter 12 Fire Safety of the LBL Health and Safety Manual is strictly required. The Accelerator Operational Safety Procedure OSP-Rev. 2 [Massoletti, 1992c] and Light Source Procedures (LSPs) that are referenced therein govern all accelerator activities. The Experimental Systems Activity Hazard Document and Conduct of Operations Procedures referenced therein govern beamline activities. There will be a companion set of AHDs and COPs for the experimental areas, as needed. The ALS User Plan provides that no beamline will be constructed nor will any experiment be approved without a rigorous safety analysis according to detailed procedures now under development [Schlachter, 1992]. Fire-safety training, inspections, and drills are conducted. A fire evacuation plan is included in the Building 6 Complex Emergency Plan that defines escape routes and personnel responsibilities and actions. An annual drill is conducted to test personnel response.

5.3.9 Fire Safety Analysis Summary

(1) Hazard Event: Room Fire

Initiating Occurrence

A room fire could be initiated by ignition of combustible materials (such as solvent, machining oils, flammable liquids, and flammable gases) resulting from welding operations, equipment failure, improper equipment maintenance, personnel failure, and earthquakes.

Method of Detection

Fire is detected by means of smoke detectors and personnel observation. Activation of smoke detectors and sprinkler flow automatically trigger an audible alarm. Personnel can trigger manual alarms.

Method of Detection

Fire is detected by means of smoke detectors and personnel observation. Activation of smoke detectors and sprinkler flow automatically trigger an audible alarm. Personnel can trigger manual alarms.

Preventive/Mitigating Features

Building construction is according to standards contained in the 1985 Uniform Building Code and is designed according to standards of the 1985 Life Safety Code. Electrical installation is according to standards in the National Electric Code [NFPA, 1990]. There is an automatic, wet-pipe sprinkler system. There are three standpipes, six hose cabinets, and 25 fire extinguishers throughout the building. There is an automatic smoke control system. Flammable liquids and gases and reactive chemicals, if any, will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Samples of flammable liquids will be limited according to the 1988 Uniform Fire Code. There will be gas detection devices in areas containing flammable gases. The ALS alarm system is directly connected to the LBL Fire Department, which is located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. There is a fire evacuation plan and annual drills. Administrative controls include OSPs, AHDs, LSPs, COPS, adherence to Chapter 12 Fire Safety of the LBL Health and Safety Manual, mandatory safety analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Medical treatment is available at LBL.

Consequences

Possible consequences of a room fire include loss of the affected area, smoke and water damage to the building and equipment, shutdown of operations, and injury to personnel from smoke inhalation and burns. From Table 4-4, the consequence level is judged to be low.

Probability

From the discussion in Section 5.3.7, the fire load in the ALS building is minimal. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of low results in a risk of negligible.

(2) Hazard Event: Room Fire Involving Radioactive or Toxic Materials

Initiating Occurrence

A room fire could be initiated by ignition of combustible materials (such as solvent, machining oils, flammable liquids, and flammable gases) resulting from equipment failure, improper equipment maintenance, personnel failure, and earthquakes.

Method of Detection

Fire is detected by means of smoke detectors and personnel observation. Activation of smoke detectors and sprinkler flow automatically trigger an audible alarm. Personnel can trigger manual alarms.

Preventive/Mitigating Features

Building construction is according to standards contained in the 1985 Uniform Building Code and is designed according to standards of the 1985 Life Safety Code. Electrical installation is according to standards in the 1990 National Electric Code. There is an automatic, wet-pipe sprinkler system. There are three standpipes, six hose cabinets, and 25 fire extinguishers throughout the building. There is an automatic smoke control system. Flammable liquids and gases, toxic materials, and radioactive materials, if any, will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Samples of flammable liquids and gases and toxic materials will be limited according to the 1988 Uniform Fire Code. There will be gas detection devices in areas containing flammable gases. The LBL alarm system is directly connected to the Fire Department located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. There is a fire evacuation plan and annual drills. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 12 Fire Safety of the LBL Health and Safety Manual, mandatory safety analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Medical treatment is available at LBL.

Consequences

Possible consequences of a room fire involving radioactive or toxic materials include loss of the affected area, smoke and water damage to the building and equipment, shutdown of operations, release of radioactive or toxic materials and injury to personnel from smoke inhalation, inhalation of toxic or radioactive materials, and burns. From Table 4-4, the consequence level is judged to be medium.

Probability

Administrative controls on the storage and use of radioactive or toxic materials and strict adherence to limits on quantities make significant releases of material unlikely (see Section 5.4). From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in a risk of low.

(3) Hazard Event: Equipment Fire

Initiating Occurrence

An equipment fire could be initiated by an electrical short, component failure, operator error, or improper maintenance.

Method of Detection

Fire is detected by means of smoke detectors and personnel observation. Activation of smoke detectors and sprinkler flow automatically trigger an audible alarm. Personnel can trigger manual alarms.

Preventive/Mitigating Features

Building design is according to standards contained in the 1985 Life Safety Code. Electrical installation is according to standards in the 1990 National Electric Code. There is an automatic, wet-pipe sprinkler system. There are three standpipes, six hose cabinets, and 25 fire extinguishers throughout the building. There is an automatic smoke control system. The LBL alarm system is directly connected to the Fire Department located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. There is a fire evacuation plan and annual drills. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 12 Fire Safety of the LBL Health and Safety Manual, mandatory safety analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Medical treatment is available at LBL.

Consequences

Possible consequences of an electrical fire include loss of the affected equipment, water damage to the building, shutdown of operations, and injury to personnel from smoke inhalation and burns. From Table 4-4, the consequence level is judged to be low.

Probability

The history of electrical fires at LBL has demonstrated that the probability of electrical fires is small. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of medium.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of medium results in a risk of low.

5.4 Hazardous Materials

The ALS has been designed and will be operated as a Group B, Division 2 facility pursuant to the 1985 Uniform Building Code. The Group B occupancy designation permits the handling of limited quantities of hazardous materials consistent with the facility design. Hazardous materials are classified according to the guidelines in Title 29 of the Code of Federal Regulations [OSHA, 1988]. DOE Order 3790.1A Federal Employee Occupational Safety and Health Program [DOE, 1984] is also applicable. Administrative procedures to be developed will limit the quantity of hazardous materials in use at the ALS to those permitted by provisions of the 1991 Uniform Building Code for Group B, Division 2 occupancy. Hazardous material safety requirements included in the 1991 code will be incorporated where appropriate. Operations involving hazardous materials in excess of the allowable limits will not be authorized.

Future facility maintenance and user research activities may involve the preparation, storage, transport, and handling of hazardous, toxic, carcinogenic, biologically active, and radioactive materials. These operations will follow federal and LBL standards, building and fire codes, and procedures, as described above. An updated inventory of hazardous materials will be maintained by the ALS EH&S Group. Equipment using hazardous materials will be reviewed as part of the experimental approval process described in Sections 3.5 and 6.4.4 and, if appropriate, beamline review process described in Section 6.3.4. All equipment will be inspected on arrival at the ALS by the EH&S Group and by the Operations Coordinators for compliance with applicable EH&S regulations. All ALS users are required to provide on the Experimental Form a list of materials involved in their experiment for review by the ALS EH&S Group before approval for their experiments will be given. All hazardous equipment and materials will be reviewed by the ALS EH&S Group to determine if an Operational Safety Procedure (OSP) is required, in accordance with the requirements given in Chapter 1 (Appendix B) of the LBL Health and Safety Manual. If required, an OSP will be prepared as described in Section 6.1

5.4.1 Hazardous Materials Quantities

The 1991 Uniform Building Code sets limits for a control zone in a Group B, Division 2 occupancy building. The ALS building will be one control zone. Establishing additional control zones within the ALS building would require construction of enclosures with one-hour fire walls, appropriate exits, and other steps, which are not now anticipated. Examples of materials and their maximum quantities allowed in one control zone for B-2 occupancy include:

combustible liquid	120 gallons
flammable liquid	15 gallons
flammable gas	750 cubic feet (STP).

The aggregate quantities can be doubled for a sprinklered building, such as the ALS building. The aggregate quantities can be doubled again if specified storage procedures are followed. The maximum quantities allowed in the ALS building then become:

combustible liquid	480 gallons
flammable liquid	60 gallons (250 liters)
flammable gas	3000 cubic feet (STP).

These are relatively large quantities, which it will be easy to avoid exceeding at the beginning of ALS operations. In addition, it is likely that the largest quantities of chemicals will be stored and/or used in laboratories and work areas outside of the ALS building. Volumes of hazardous materials will not exceed applicable building and fire code limits, and required venting and containment systems will be provided.

5.4.2 Hazardous Materials Control

A Conduct of Operations Procedure has been developed to control handling of hazardous materials by users in the ALS building [Perdue, 1993a]. All chemicals and potentially flammable, explosive, and other hazardous materials will be listed by users on Schedule A of the Experiment Form. Before they are brought to the ALS, instructions will be provided to the users by the ALS Industrial Hygienist and/or the Head of the Beamline Operations Section detailing shipping, packaging, reception, transportation, and storage of such materials. Similar instructions will be provided when such materials are to be transferred to the ALS from stores or another locations at LBL.

Records of all hazardous materials will be maintained by the Beamline Operations Section. Records to be maintained include arrival data, quantity, and location of each hazardous material. Chemicals will be stored in the special storage areas created in Building 10 adjacent to the ALS building under the supervision of the Head of the Beamline Operations Section. Smaller quantities will be allowed onto the ALS floor. The Head of the Beamline Operations Section will be responsible for ensuring that the quantities do not exec the building limits described in the Section 5.4.1.

The Head of the Beamline Operations Section and Industrial Hygienist will be jointly responsible for informing users about safe handling, storage, use, ventilation (e.g., vented gas cabinets and exhaust system), and disposal of materials. They are also responsible for developing emergency plans, where needed in addition to the procedures specified in the Building 6 Complex Emergency Plan. Furthermore, the Industrial Hygienist will be responsible for ensuring that potential personnel and environmental exposures are analyzed and for recommending appropriate control measures. Material Safety Data Sheets for all chemicals used in experiments will be maintained by the Head of the Beamline Support Section and reviewed by the Industrial Hygienist. The relevant MSDSs for each experiment will also be posted with the approved Experiment Form at the experimental station.

At this time, it is not known what materials will be brought to the ALS by the users because proposals for specific experiments have not been called for. Table 5-3 lists categories of hazardous materials, with examples typical of a materials science laboratory for research on semiconductors, catalysts, and superconductors, and shows quantities permitted per control area for B-2 occupancy. In cases where UBC exempt quantities have not been established, the LB L Environment, Health, and Safety Division and the ALS EH&S Group will determine allowable quantities. As noted earlier, most materials will be stored and used in sample preparation areas outside the ALS building.

Table 5-3. Categories of Hazardous Materials.

Category and Examples	Threshold Limit Value for Chemical Substances in the Work Environment [ACGIH, 1988-89]	1988 UBC/UFC B-2 Exempt Aggregate Quantity per Control Area
TOXIC GAS		1300 ft^3 in vented enclosure
Boron trifluoride	1 ppm	
Hydrogen chloride	5 ppm	
HIGHLY TOXIC GAS		40 ft^3 in vented enclosure
Arsenic pentafluroide	not listed	
Arsine	0.05 ppm	
Diborane	0.1 ppm	
Germane	0.2 ppm	
Nitric oxide	25 ppm	
Phosphine	0.3 ppm	
Phosphorous pentafluoride	0.1 ppm	
FLAMMABLE GAS		1500 ft^3
Acetylene	not listed	
Arsenic pentafluoride	not listed	
Arsine	0.05 ppm	
Carbon monoxide	50 ppm	
Diborane	0.1 ppm	
Ethylene	not listed	
Germane	0.2 ppm	
Hydrogen	not listed	
Methane	not listed	
Phosphine	0.3 ppm	
FLAMMABLE GAS, LIQUEFIED		30 gallons
Propane	not listed	
PYROPHORIC GAS		20 ft^3
Phosphine	0.3 ppm	
Diborane	0.1 ppm	
Silane (5% hydrogen)	5 ppm	
OXIDIZING GAS		3000 ft^3
Oxygen	not listed	
PYROPHORIC LIQUID		2 pounds
Trimethylaluminum	not listed	
Trimethylgallium	not listed	
OXIDIZING LIQUID		20 gallons
Hydrogen peroxide	1 ppm	

Table 5-3. Categories of Hazardous Materials (cont.).

Category and Examples	Threshold Limit Value for Chemical Substances in the Work Environment [ACGIH, 1988-89]	1988 UBC/UFC B-2 Exempt Aggregate Quantity per Control Area
CORROSIVE LIQUID		200 gallons
Acetic acid	10 ppm	
Ammonium hydroxide	not listed	
Bromine	0.1 ppm	
Formic acid	5 ppm	
Hydrochloric acid	5 ppm	
Hydrofluoric acid	3 ppm	
Nitric acid	2 ppm	
Potassium hydroxide	2 mg/m^3	
Sodium hydroxide	2 mg/m^3	
Sulfuric acid	1 mg/m^3	
FLAMMABLE LIQUID		20 gallons
Acetone	750 ppm	
Ether (ethyl)	400 ppm	
Ethyl alcohol	1000 ppm	
Hexane (isomers)	500 ppm	
Isopropyl alcohol	400 ppm	
Methyl alcohol	200 ppm	
Methyl ethyl ketone	200 ppm	
TOXIC LIQUID		200 gallons
Carbon tetrachloride	5 ppm	
Trichloroethane (1,1,2)	10 ppm	
HIGHLY TOXIC LIQUID		2 pounds
Bromine trifluoride		
TOXIC SOLID		2000 pounds
Arsenic	10 µg/m^3	
Barium carbonate	0.5 ml/m^3	
Barium hydroxide		
Barium oxide	0.5 mg/m^3	
Beryllium	2 µg/m^3	
Gallium arsenide	not listed	
Mercury	0.05 mg/m^3	
Phosphorous oxide	not listed	
Selenium	0.2 mg/m^3	
Thallium	not listed	
OTHER SOLID		
Chromic acid	0.05 mg/m^3	
Lithium fluoride	not listed	
Lithium hydroxide	0.025 mg/m^3	

5.4.3 Handling Gases

Dedicated gas cabinets will be provided. Gas cylinders for flammable and toxic gases will reside in the gas cabinets at all times, except during the exchange (loading and unloading process). The gas is fed from the gas cabinet directly to the equipment.

The gas cabinets will have brackets to restrain the gas cylinders and valves that can be operated from outside the cabinet. A vent will connect the gas cylinders to the ALS exhaust for hazardous gases.

Hazardous gas cylinders will be handled according to LBL hazardous gas receival, storage, and transportation procedures in accordance with the LBL Chemical Hygiene and Safety Plan. Delivery of hazardous gas cylinders will follow procedures to be developed in an OSP.

Experimental equipment will be ventilated as required by Chapter 13 of the LBL Health and Safety Manual. Highly toxic gases will require double-wall pipe, detectors, automatic-shutoff devices, and restrictive flow orifices. Cabinets will be sprinklered.

5.4.4 Toxic Gases

To determine the level of risk involved in the handling of highly toxic gases, reference was made to a dispersion-modeling and risk-assessment study that was conducted on the use of arsine [Dames & Moore, 1990]. This gas was chosen for analysis because it has the highest toxicity rating of gases that could conceivably be used in the ALS building. Arsine gas is a potent toxic agent that produces fulminating hemolysis with subsequent renal failure following acute high-dose exposure. Human-exposure data and studies in laboratory rats and mice have shown a very steep dose-response relationship, which results in a very sharp threshold between tolerated and toxic does of arsine. A human health criteria of 1 ± 0.5 ppm is an appropriate extrapolation of the toxicological database for arsine.

Results for several accidental release scenarios were modeled to estimate potential impacts to nearby individuals for a release of arsine from a laboratory roof vent and release of arsine during handling of a compressed gas cylinder outdoors next to the laboratory. The study found that, depending on the prevailing wind direction at the time of a release, airborne concentrations above the estimated no-effect level in humans may occur on the premises of LBL. However, in many case, because of its narrow width and limited areal extent, potential exposures are likely to be transient. Adverse effect that potentially could be associated with a plume on the LBL premises should not produce significant observable symptoms. It is unlikely that exposure at these levels will result in significant or irreversible adverse effects in potentially exposed individuals on or off the LBL site.

The effects of an accidental arsine leak caused by a single-point failure (gas-line rupture) in a laboratory room have also been calculated [Buerer, 1990]. Several assumptions were made: (1) gas cylinders are stored in gas cabinets resulting in a maximum length for any single gas line of 50 feet and an OD. of 0.25 inch; (2) single-point failure consists of a section of the stainless steel gas line ruptures or breaks; (3) the toxic gas monitor senses arsine in the room at the Threshold Limit Value of 0.05 ppm and immediately shuts off the cylinder and isolates the leak to the longest length of tubing; (4) the room exhaust ventilation continues to function at its design rate, thereby causing the air in the room to mix; and (5) the arsine pressure in the gas line is regulated to 5 psi (the maximum that researchers would require). The resulting concentration of arsine gas in the room following such a failure was found to be below one-half the Immediately Dangerous to Life or Health (IDLH) level of 6 ppm. The IDLH level is that concentration determined by NIOSH that would not cause escape-impairing symptoms or irreversible health effects for a 30-minute exposure.

5.4.5 Administrative Controls

A host of administrative controls are described elsewhere in this FSAD, primarily in Section 4, that bear on hazardous materials safety. Adherence to Chapter 7 Cryogenic Fluid Safety and Chapter 13 Gases, Flammable and/or Compressed of the LBL Health and Safety Manual is strictly required. The LBL Chemical Hygiene and Safety Plan [LBL, 1992c] governs all operations involving hazardous chemicals and provides a framework for a comprehensive chemical hygiene program. Guidelines for Generators of Hazardous Chemical Waste at LBL and Guidelines for Generators of Radioactive and Mixed Waste at LBL [LBL, 1991b] govern handling and disposal of hazardous wastes. The Accelerator Operational Safety Procedure OSP-Rev. 2 and LSPs referenced therein govern all accelerator activities. The Experimental Systems Activity Hazard Document and Conduct of Operations Procedures referenced therein govern beamline activities. There will be a companion set of AHDs and COPs for the experimental areas, as needed. The ALS User Plan provides that no beamline will be constructed nor will any experiment be approved without a rigorous safety analysis according to detailed procedures, as described in Sections 6.3.4 and 6.4.4. The ALS User Plan also provides for a hazardous-material control program, as outlined in Section 5.4.2. Safety training is required for all staff and visiting scientists, as described in Sections 3.5.6 and 6.5.1.

5.4.6 Hazardous Materials Safety Analysis Summary

(1) Hazard Event: Uncontrolled Chemical Reaction

Initiating Occurrence

Uncontrolled chemical reactions can occur when incompatible chemicals are mixed as a result of personnel error, improper maintenance, or earthquakes.

Method of Detection

Uncontrolled chemical reactions are detected by means of gas detectors, smoke detectors, and observation by personnel.

Preventive/Mitigating Features

When not in use for experiments, flammable liquids and gases and reactive chemicals will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Samples of flammable liquids will be limited according to the 1988 Uniform Fire Code. Use of chemicals will be limited to ventilated fume hoods. Incompatible chemicals will be segregated. Shelving is seismically restrained. There is an automatic, wet-pipe sprinkler system. There are three standpipes, six hose cabinets, and 25 fire extinguishers throughout the building. There is an automatic smoke control system. The ALS alarm system is directly connected to the LBL Fire Department, which is located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to the LBL Chemical Hygiene and Safety Plan, Chapter 13 Gases, Flammable and/or Compressed and Chapter 30 Research Equipment of the LBL Health and Safety Manual, mandatory EH&S analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Design reviews of piping, exhaust, and alarm systems for beamlines are mandatory. Medical treatment is available at LBL.

Consequences

Arsine is the most toxic chemical expected at the ALS. Release scenarios show no significant or irreversible adverse effects to individuals on or off the LBL site. In addition, owing to the limited quantities of the less toxic materials in use at the ALS, uncontrolled chemical reactions would not result in a significant injury or occupational illness, nor would the have a significant impact on the environment. From Table 4-4, the consequence level is judged to be extremely low.

Probability

Segregation of chemicals and adherence to administrative procedures make the probability of an uncontrolled chemical reaction extremely low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk

From the risk matrix in Table 4-6, a consequence level of extremely low and a probability level of extremely low results in a risk of negligible.

(2) Hazard Event: Chemical Exposure

Initiating Occurrence

Exposure to chemicals can occur when toxic material, acids, or caustic materials are spilled as a result of personnel error or earthquake.

Method of Detection

Exposure is detected by the affected personnel.

Preventive/Mitigating Features

When not in use for experiments, flammable liquids and reactive chemicals will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Samples of flammable liquids will be limited according to the 1988 Uniform Fire Code. Use of chemicals will be limited to ventilated fume hoods. Incompatible chemicals will be segregated. Shelving is seismically restrained. The ALS alarm system is directly connected to the LBL Fire Department, which is located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to the LBL Chemical Hygiene and Safety Plan, mandatory EH&S analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Design reviews of piping, exhaust, and alarm systems for beamlines are mandatory. Medical treatment is available at LBL.

Consequences

The consequence of exposure to chemicals is personnel injury, including inhalation of toxic material. From Table 4-4, the consequence level is judged to be low.

Probability

Proper storage of chemicals, use of ventilated fume hoods, and adherence to administrative procedures reduce the probability of a chemical exposure, but the routine use of chemicals causes the probability to remain medium. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of medium.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of medium results in a risk of low.

(3) Hazard Event: Exposure to Cryogenic Temperature

Initiating Occurrence

Exposure to cryogenic temperature can occur as a result of cryogenic fluid leakage or personnel error.

Method of Detection

Exposure is detected by the personnel affected.

Preventive/Mitigating Features

Cryogenic systems are designed according to ASME pressure-vessel codes [ASME, 1986]. Piping is designed according to applicable codes. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 7 Cryogenic Fluid Safety of the LBL Health and Safety Manual, mandatory EH&S analysis of all experiments, and employee and visitor training. Design reviews of piping, exhaust, and alarm systems for beamlines are mandatory. Medical treatment is available at LBL.

Consequences

The consequence of exposure to cryogenic temperature is injury to the affected personnel. From Table 4-4, the consequence level is judged to be low.

Probability

Proper design of cryogenic systems and adherence to administrative procedures reduce the probability of exposure to cryogenic temperature, but the routine use of cryogens causes the probability to remain medium. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of medium.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of medium results in a risk of low.

(4) Hazard Event: Compressed Gas Explosion

Initiating Occurrence

Compressed gas explosion can occur as a result of damage to gas cylinders, valves, or gas lines due to personnel error or earthquake.

Method of Detection

Detection of a compressed gas explosion is by observation of personnel in the area

Preventive/Mitigating Features

When not in use for experiments, gases will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Gas cylinders are designed to ASME pressure-vessel codes. Pressure regulators and relief valves are installed on gas lines. Confinement of an explosion is provided by walls of the building. The ALS alarm system is directly connected to the LBL Fire Department, which is located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 13 Gases, Flammable and/or Compressed of the LBL Health and Safety Manual, mandatory EH&S analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Design reviews of piping, exhaust, and alarm systems for beamlines are mandatory. Medical treatment is available at LBL.

Consequences

Consequences of a compressed gas explosion include injury to personnel, damage to equipment, and shutdown of operations. From Table 4-4, the consequence level is judged to be medium.

Probability

Proper storage of compressed gases, properly designed gas cylinders, and adherence to administrative procedures reduce the probability of compressed-gas explosions to low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in a risk of low.

(5) Hazard Event: Gas Explosion (Hydrogen, Oxygen, Acetylene)

Initiating Occurrence

A gas explosion involving hydrogen, oxygen, or acetylene can occur as a result of damage to gas cylinders or leakage in gas lines, from operator error, or from an electrical spark.

Method of Detection

A gas explosion is detected by personnel in the affected area.

Preventive/Mitigating Features

When not in use for experiments, flammable gases will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Gas systems will exhaust to the atmosphere. Gas-detection equipment will be interlocked. There is an automatic, wet-pipe sprinkler system. There are three standpipes, six hose cabinets, and 25 fire extinguishers throughout the building. There is an automatic smoke control system. The ALS alarm system is directly connected to the LBL Fire Department, which is located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 13 Gases, Flammable and/or Compressed of the LBL Health and

Safety Manual, mandatory EH&S analysis of all experiments, employee and visitor training, and no smoking in the ALS building. Design reviews of piping, exhaust, and alarm systems for beamlines are mandatory. Medical treatment is available at LBL.

Consequences

An explosion can cause a fire, damage to equipment, injury to personnel, and shutdown of operations. From Table 4-4, the consequence level is judged to be medium.

Probability

Proper storage of flammable gases in fire-resistant cabinets, the use of atmospheric exhausts on gas systems, and adherence to administrative procedures reduce the probability of a gas explosion involving hydrogen, oxygen, or acetylene to low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in risk of low.

(6) Hazard Event: Inhalation, Ingestion, or Dermal Exposure to Toxic or Carcinogenic Material

Initiating Occurrence

Inhalation, ingestion, or dermal exposure to toxic or carcinogenic material can occur as a result of personnel error, including improper material handling.

Method of Detection

Inhalation, ingestion, or exposure is detected by the affected personnel and by bioassay.

Preventive/Mitigating Features

When not in use for experiments, toxic or carcinogenic chemicals will be stored in UL and/or FMEC approved metal fire-resistant storage cabinets. Samples of chemicals will be limited according to the 1988 Uniform Fire Code. Use of chemicals will be limited to ventilated fume hoods or other ventilated structures that are designed to applicable codes. There are emergency showers. The ALS alarm system is directly connected to the LBL Fire Department, which is located less than 200 feet from the ALS building. The automatic alarm is backed up by telephone communication. Administrative controls include Operational EH&S Procedures, COPS, LSPs, adherence to the LBL Chemical Hygiene and Safety Plan, mandatory EH&S analysis of all experiments, and employee and visitor training. Protective clothing and self-contained breathing apparatus are available. Medical treatment is available at LBL.

Consequences

The consequence of inhalation, ingestion, or dermal exposure to toxic, or carcinogenic material is personnel injury. From Table 4-4, the consequence level is judged to be medium.

Probability

Proper storage of toxic or carcinogenic materials in fire-resistant cabinets, the use of limited quantities of materials, the use of ventilated systems, and adherence to administrative procedures reduce the probability of inhalation, ingestion, or dermal exposure to toxic, or carcinogenic material to extremely low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of extremely low results in a risk of negligible.

(7) Hazard Event: Oxygen-Deficient Atmosphere

Initiating Occurrence

Oxygen-deficient atmospheres can be generated in confined spaces, such as the accelerator enclosures and the tunnel between Building 80 and the ALS building, by evolution of toxic or non-toxic gases or vapors. Examples are rapid release of a full 160-liter liquid nitrogen dewar in an accelerator cave or tunnel and plumbing-line failure during liquid-nitrogen boil-off that is used to bring portions of the vacuum system to atmospheric pressure for installation, modifications, maintenance, and repairs. Hardware or interlock failure and operator error are causes of such events.

Method of Detection

Oxygen deficiency is detected by gas monitors.

Preventive/Mitigating Features

The accelerator cave and tunnels are forced-air ventilated. Entry into an accelerator tunnel or an ALS building tunnel that has been designated as a confined space requires the completion of a confined-space work entry permit with approval by the LBL Environment, Health, and Safety Division, as necessary. Nitrogen dewars are only inside enclosures while in use; exhaust blowers and/or air-conditioning systems must be on when a dewar is in an enclosure. Signs are posted to alert personnel of a potential suffocation hazard. The nitrogen supply line outside the tunnel is fitted with an orifice to limit the nitrogen supply to less than 1% of the fresh-air supply. A normally closed magnetic valve will shut off the nitrogen should the fresh-air supply drop below normal

Consequences

The consequence of oxygen deficiency is personnel injury due to asphyxiation. From Table 4-4, the consequence level is judged to be medium.

Probability

Forced-air ventilation, the limited supply of nitrogen, and administrative procedures reduce the probability of oxygen deficiency to extremely low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of extremely low results in a risk of negligible.

5.5 Electrical Safety

5.5.1 Electrical Safety Systems

Electrical protection is achieved by scrupulous adherence to applicable standards, codes, and directives governing design, operation, and maintenance of electrical equipment, including the 1990 National Electric Code, the Electrical Safety Requirements for Employee Workplaces [NFPA, 1988], and the National Electrical Safety Code [ANSI, 1993]. All installation and maintenance of electrical equipment is checked by LBL Maintenance and Operations(M&O) supervisory personnel or ALS electronic-maintenance-shop personnel. In addition, all installations and operations must be in accordance with the latest edition of Chapter 8 Electrical Safety of the LBL Health and Safety Manual, which defines responsibilities of personnel, principles of implementation of safety procedures, requirements for design and construction of equipment, means of accident prevention, and lockout/tagout procedures. Cabinet doors to high-voltage equipment are interlocked to turn off circuits when doors are opened. Enclosures with equipment of more than 600 volts are marked in accordance with National Electric Code paragraph 370-52(e) "Danger High Voltage Keep Out." Enclosures containing equipment with less than 600 volts will have warning signs of a similar nature. Stored-energy devices, such as capacitors, will have automatic discharging devices. Grounding and bonding of electrical equipment cabinets, electromechanical devices, including magnet iron, and girder support assemblies are in accordance with the National Electric Code. Special equipment will be reviewed by the LBL Electrical Safety Subcommittee for operational safety. Interlocks for electrical equipment are tested as described in Section 6.5.2 and as specified in Conduct of Operations Procedure EC 02-02 ALS Radiation Interlock System Testing Procedure [Ritchie, 1993]. Bypassing equipment interlocks not associated with the personnel safety system is governed by EE 01-01 Equipment Interlock Bypass Procedure [Gregor, 1993]).

5.5.2 Electrical System Operations

Activities will involve operation and maintenance of power supplies, rf equipment, high-field magnets, vacuum apparatus, and scientific instrumentation.

<u>Injection System</u>

The electrical power to operate the ALS is distributed to most of the equipment at 480 V AC, 3 phase, with a grounded WYE system. Other power equipment and control equipment is operated from a 115/208 volt system. The installation of this distribution equipment is according to standard industrial practice for equipment of this type and conforms to applicable codes. All sources of exposed voltages above 50 volts are isolated by covers and enclosures. Access to all voltages above 50 volts rms is by means of screw-on panels, each of which contains no less than four screws or bolts, or by means of interlocked, hinged doors or covers. The frames and chasses of all electrical enclosures or cabinets are connected to a good electrical ground with a conductor capable of handling any potential fault current. Automatic-discharge devices are used on equipment with stored energy of 5 joules or more. Suitable manual grounding devices that are readily visible are provided to short to ground all dangerous equipment while work is being performed.

Cabinets housing high-voltage equipment in the linac vault and the booster-synchrotron area are the gun modulator, the klystron modulator, and the booster rf-system power supplies and associated equipment. All entry doors to these cabinets are electrically interlocked so that the high voltage is turned off when the door is opened. In addition, grounding sticks are provided within these high-voltage areas. High pulsed voltages are also present in the fast-kicker power-supply enclosures that provide the power for the injection and extraction kickers, the septa, and the bend magnets of the booster. Removal of the access panels to this equipment automatically interrupts the high-voltage power supply to that unit.

The magnet power supplies necessary for booster operation are located inside the booster area. When beam is being injected into the booster, this becomes an exclusion area and access is controlled.

Storage Ring

The general EH&S requirements detailed for the injection system also apply to the storage ring. Hazards peculiar to the storage ring are as follows. The magnet power supplies and rf power equipment necessary for storage-ring operation are situated inside the ring area. When beam is being injected into the storage ring, this becomes an exclusion area and access is controlled. However, both the magnet power supplies and the rf-power equipment may be operated without beam while this inner area is occupied by ALS personnel. The power supplies for the linac-to-booster transfer line are automatically turned off, thereby shutting down the electron beam whenever the area inside the storage ring tunnel is entered. As with the injection-system hardware, the individual cabinets of high-voltage equipment are all interlocked so that the power is turned off automatically when the door is opened. In addition, the high-current dipole, quadrupole, and sextupole magnet bus systems are covered.

Beamlines

The general EH&S requirements detailed for the injection system also apply to the beamlines. Electronics racks and cable trays will conform to applicable codes.

5.5.3 Lockout/Tagout Procedures

All lockout/tagout procedures are done in accordance with CFR 1910.147 and with Chapter 8, Appendix A Lockout/Tagout (LOTO) of Hazardous Energies for Servicing and Maintenance of Equipment and Systems of the LBL Safety and Health Manual. Appendix A describes the lockout and tagout procedures used to secure mechanical and electrical systems for the purposes of performing work on them. This procedure mandates strict conformance when it is necessary to work on systems that may contain stored energy. This procedure covers the servicing, maintenance, and modification of machines and equipment in which the unexpected energizing, start-up, or release of stored energy in the machines or equipment could cause injury to an employee or damage to the machine or equipment. Specific LOTO instructions applicable to the ALS are contained in ALS 09-01 Electrical Logout/Tagout (LOTO) Supplemental Procedure for the ALS [Gregor and Jones, 1993].

Appendix A further provides that LOTO of machines and equipment shall only be performed by authorized employees. Typically, LOTO authorization is assigned to the cognizant project or lead engineer, mechanical designer, electronic coordinator, plant maintenance technician, mechanical technician, electronic technician, plant electrician, or construction and maintenance technician. Appendix A provides for both unwritten and written LOTO procedures. Written procedures must be approved by line management and included in the systems Operational Safety Procedure, if one exists.

5.5.4 Non-Ionizing Radiation Safety

LSP-016 Injector Commissioning Trainee Startup Checklist [Massoletti, 1992d] and LSP-021 Booster RF Power Systems Operating Procedure [Taylor, 1992] must be followed prior to and during operating of the ALS injector rf systems. LSP-040 Storage Ring RF Power System Operating Procedure [Taylor, 1993] must be followed prior to and during operation of the ALS storage ring rf system.

Injection System

The rf system for the linac uses two high-power (25 MW peak) klystrons operating at a frequency of 2997.9 MHz. All of the high-power rf is contained within the vacuum waveguide or accelerator cavities and poses no health hazard. The rf system for the booster synchrotron operates at a frequency of 499.65 MHz and an average power of 10.9 kW. The rf power amplifiers were manufactured to a specification [ANSI, 1982] which required that rf levels from these units be below 1 mW/cm^2 at 5 cm from the source. Leakage measurements will be made by an EH&S radiation safety technician at least once per year in order to ensure continued conformance with the specification.

Magnetic fields of the order of 1 kG developed by a large electromagnet are used for focusing the electron beam in the klystrons. Signs warning of this hazard will be posted near the magnets.

Storage Ring

The rf system for the storage ring operates at a frequency of 499.65 MHz and at an average power level of 214 kW. The specification for the rf-power amplifier systems required that leakage levels from the cavities associated with this system be below 1 mW/cm^2 at 5 cm from the source. Measurements will be made to confirm that these levels are in conformance with the specification. The power from the klystron is divided equally between two rf cavities by a "Magic Tee" in a power-dividing system with standard transmission line components. Each flange joint in the transmission-line system is a potential source for nonionizing radiation. Leakage measurements will be made during the commissioning of these systems to determine that the rf leakage is below 1 mW/cm^2 exterior to the rf waveguides and cabinet. During operation, power levels will be computer monitored continuously in all stages of the transmission-line system. Radiation-loss measurements will be made at least once per year to ensure system integrity.

5.5.5 Electrical Safety Analysis Summary

(1) Hazard Event: Electrical Shock

Initiating Occurrence

Electrical shock can occur as the result of an electrical short-circuit, improper maintenance of equipment, interlock failure on high-voltage equipment, or failure to follow lockout-tagout procedures

Method of Detection

The primary means of detection is observation by personnel in the affected area. Loss of electrical power may also occur.

Preventive/Mitigating Features

Installation of equipment is according to 1990 National Electric Code standards. All hazardous power supplies are enclosed in grounded enclosures. Equipment fed by high-voltage power supplies, above 5 kV, are fully enclosed. High-voltage equipment is interlocked. Interlocks are fail-safe, redundant, and testable. Provision is made for grounding wands. Circuit breakers have lockout tabs. Equipment has current-limiting circuits. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 8 Electrical Safety of the LBL Health and Safety Manual, mandatory EH&S analysis of all experiments, and employee and visitor training. Enclosures may only be opened when two authorized persons are present and published procedures must be followed. Interlock bypass operations must follow prescribed procedures. Warning signs are posted. Medical treatment is available at LBL.

Consequences

The consequences of electrical shock include injury to personnel and damage to equipment. From Table 4-4, the consequence level is judged to be medium.

Probability

The use of interlocks and grounding and adherence to the National Electric Code and ALS administrative procedures reduces the probability of electrical shock to low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in a risk of low.

(2) Hazard Event: Exposure to nonionizing radiation

Initiating Occurrence

High-power rf systems associated with the accelerator pose a burn hazard through exposure to nonionizing radiation. Exposure can occur as a result of equipment or interlock failure, operator error, or leaky waveguide flanges.

Method of Detection

Nonionizing radiation is detected by means of area monitoring with radiation detectors and by visual inspection of waveguides.

Preventive/Mitigating Features

All hazardous power supplies are enclosed in grounded enclosures. Equipment fed by high-voltage power supplies (above 25 kV) are fully enclosed and access is controlled by electrical interlocked and mechanically locked door that can only be opened by an interlocked key system. The section of switchable coaxial feeder is interlocked to the rf power system to prevent operation if the feeder is moved. Interlocks are fail-safe, redundant, and testable. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 8 Electrical Safety of the LBL Health and Safety Manual, and employee training. Inspections following prescribed procedures must be followed before operation of the rf power systems, with special attention to the waveguide feed. Leakage measurements at the rf sources will be made at least annually at identified points or after any significant modification. Opening modulator cabinet doors requires two persons from an authorized list and published procedures must be followed. Warning signs are posted. Medical treatment is available at LBL.

Consequences

The consequence of exposure to nonionizing radiation is injury to personnel. From Table 4-4, the consequence level is judged to be medium.

Probability

For an individual to be exposed to nonionizing radiation inside the accelerator enclosures, one or more events would have to occur. The interlock system would have to fail. Failure of the interlock system could include an interlock bypass. If there were an equipment failure or leaky waveguide flanges, the area radiation monitors would have to fail. From experience at other accelerator facilities and from one-year ALS commissioning experience with the linac and the booster, it is judged that the probability of such failure is low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in a risk of low.

(3) Hazard Event: Exposure to High Magnetic Forces

Initiating Occurrence

Strong pulsed and DC magnetic fields may be created near the accelerator and transport magnets. The continuous magnetic fields near the beam-transport magnets can locally exceed 5 Gauss. Exposure to high magnetic forces of the order of 1 T can also occur during fabrication, testing, maintenance, or installation activities on permanent-magnet insertion devices.

Method of Detection

High magnetic forces are detected by observation of personnel in the affected area.

Preventive/Mitigating Features

During normal operation, magnetic fields are generated within the accelerator enclosures and are not accessible by personnel. During commissioning and periods of testing, signs are posted warning of the magnetic-field hazard, including a specific warning concerning pacemakers. Access to high-field magnets that are operated for testing while personnel are present are posted with signs and lights during testing. Magnetic-field surveys are taken outside the accelerator enclosures. Access to insertion devices during fabrication and testing is restricted by physical barriers, enclosures, and signs. Assembly equipment is semiautomated. Non-magnetic tools are used. Small quantities of magnetic material are handled.

Consequences

Consequences to exposure to high-magnetic forces include injury to personnel and damage to magnetic material and/or equipment. Steady-state magnet-field intensities above approximately 10 Gauss may affect cardiac pacemakers and metallic implants. From Table 4-4, the consequence level is judged to be low.

Probability

Blocking access to equipment generating high magnetic fields by accelerator enclosures during operation and warning lights and signs during testing reduce the probability of exposure to high magnetic forces to medium. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of medium.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of medium results in a risk of low.

5.6 Laser Safety

Guidance for the safe use of lasers and laser systems is provided by Chapter 16 Laser Safety of the LBL Health and Safety Manual. It, in turn, is derived from Standard for the Safe Use of Lasers [ANSI, 1986].

5.6.1. Laser Safety Officer

The Laser Safety Officer of the LBL Environmental Health and Safety Department will review the initial use of lasers with researchers at the facility. The following is a partial list of responsibilities of the Laser Safety Officer:

- Reviews and approves all laser OSPs at new facilities and modifications at existing facilities that change the laser safety-control parameters.

- Provides consulting services for laser users and for EH&S and training programs.

- Conducts a required safety class for all Class 3b and Class 4 laser and laser-system users.

- Maintains the necessary records required by applicable government regulations.

- Accompanies DOE inspectors and documents any discrepancies noted; ensures that corrective action is taken where required..

- Aids in investigating any known or suspected accident resulting from a laser operation.

- Provides the correct laser warning signs for user control areas.

- Has the authority to suspend, restrict, or terminate the operation of a laser or laser system if the laser-hazard controls are considered inadequate.

5.6.2. Laser Classification and Control

The ANSI standard establishes a hazard classification scheme based on the ability of the laser beam to cause biological damage to the eye or skin. This scheme is used to place each laser into one of four classes; each laser must meet the EH&S requirements specified for its class.

Lasers or laser systems certified for a specific class by a manufacturer in accordance with the Federal Laser Product Performance Standard may be considered as fulfilling all classification requirements of this regulation. In cases where the laser or laser-system classification is not provided, or where the class level may change because of a change from the use intended by the manufacturer or because of the addition or deletion of engineering control measures, the laser or laser system shall be classified by the Laser Safety Officer.

Control measures will be applied after the laser has been properly classified. Control measures are divided into two categories:

- Engineering (protective housings, area posting, beam stops, control areas, interlocks, beam path, etc.)

- Administrative procedures (OSPs, training, eye protection, alignment procedures, etc.)

OSPs are required for all Class-3b and Class-4 laser systems. Engineering measures are almost always the preferred method for controlling access to laser radiation.

As proposals for experiments are received and before laser operation is permitted, appropriate control measures, including physical barriers, protective equipment, warning devices, and administrative procedures, will be in place for all laser and laser-system installations at the ALS, along with employee and researcher orientation and training concerning laser hazards and control and applicable EH&S regulations.

5.6.3 Laser Safety Analysis Summary

(1) Hazard Event: Laser Light Energy Transfer

Initiating Occurrence

Exposure to laser light can occur as a result of laser-beam misalignment, laser-beam scattering, laser-beam reflection, operator error, or interlock failure,

Method of Detection

Exposure to laser light is detected by means of its effect on personnel in the affected area.

Preventive/Mitigating Features

Protection (protective housings, interlocks, beam stops, eye protection, protective clothing, warning devices) appropriate to classification of laser under laser-safety classification code is provided. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 16 Laser Safety of the LBL Health and Safety Manual, and employee training. Warning signs are posted. Medical treatment is available at LBL.

Consequences

The consequence of exposure to laser light can be minor injury to personnel. From Table 4-4, the consequence level is judged to be low.

Probability

Protective devices and adherence to administrative procedures reduce the probability of exposure to laser light to low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of low results in a risk of negligible.

5.7 Visible and Near-UV Light

Visible and near-UV light is produced by synchrotron-radiation sources, particularly bend magnets and wigglers, which generate a broad, continuous spectrum of radiation that extends to long wavelengths. Long-period undulators operating at high K values may also produce near-UV light. The optical properties of visible and near-UV light, such as the reflectivity from surfaces and transmission through windows, differ from those of x-ray and VUV radiation.

5.7.1 Visible and Near-UV Light Safety Analysis Summary

(1) Hazard Event: Exposure to Visible and Near UV Light

Initiating Occurrence

Visible light or near-UV that is produced by synchrotron-radiation sources could be transported by the beamline optical system to a window or viewport where exposure could damage an observer's vision.

Method of Detection

Exposure to visible and near-UV light is detected by means of its effect on personnel in the affected area.

Preventive/Mitigating Features

Viewports and windows through which visible or near-UV could be transmitted will be covered by an opaque cover with a warning of the hazard. Administrative controls include review by the Beamline Review Committee, the Experimental Systems AHD, a COP to be written that will describe the process for removing the cover, and employee training. Verifying that the cover is in place will be included in the operations checklist for the beamline. Medical treatment is available at LBL.

Consequences

The consequence of exposure to visible or near-UV light can be minor injury to personnel. From Table 4-4, the consequence level is judged to be low.

Probability

Protective devices and adherence to administrative procedures reduce the probability of exposure to visible or near-UV light to low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of low results in risk of negligible.

5.8 Environmental Safety

5.8.1 Ozone Production

Ozone is produced when short-wavelength x-rays pass through air. This is potentially a problem in those ALS experimental areas in which x-rays exit the beamline through a thin beryllium or other type window and enter the atmosphere. In order to control this potential hazard, an exhaust system to the outside atmosphere will be provided. Before an experiment of this type is put on-line, ozone levels will be monitored and a time delay for entry into the affected area established. In experiments where high-intensity x-ray beams are allowed to pass through the atmosphere, a calculation of the ozone level will be required for review by the ALS Safety Committee.

Ozone is also produced in the accelerator enclosures by ionization of atmospheric components by the photoelectric shower produced when energetic electrons are lost to the vacuum chamber wall. The dominant reactions are:

$$
\begin{aligned}
&O_2 + h\nu \rightarrow O_2^* \\
&O_2^* + O_2 \rightarrow O_3 + O \\
&NO_2 + h\nu \rightarrow NO + O \\
&O_2 + O + (M) \rightarrow O_3 + (M).
\end{aligned}
$$

Under the conditions pertaining at the ALS (and confirmed by experience at similar facilities), the maximum production rate occurs where the maximum power is lost from the beam. In the ALS, maximum production occurs when all of the linac beam is stopped in a region where the electromagnetic shower emerges into the atmosphere, for example at the beam collimator immediately after the first bend magnet. This situation has been reviewed by the LBL EH&S Division [McCaslin, 1990c]. It was assumed that all the radiation yield from the interruption of 5 W (average power) of beam at 50 MeV is absorbed in the air, rather than in surrounding support structures. With the additional assumption of no decomposition or ventilation, it is calculated that the permissible exposure limit (or PEL) of 0.1 ppm [OSHA, 1989] is reached in about 37 minutes. When normal ventilation (3000 cu. ft./ min) and ozone recombination [George, 1965] are taken into account, the steady-state concentration is calculated to be one-tenth of PEL. Since the calculations are based on a worst case scenario, with pessimistic assumptions about the amount of energy deposited into the atmosphere within the cave, ozone production is not considered to be an issue for the accelerator enclosures. However, if an ozone odor is noticeable, monitoring equipment would be used to assess the potential hazard.

5.8.2 Ozone Safety Analysis Summary

(1) Hazard Event: Ozone Exposure

Initiating Occurrence

Ozone is produced during normal operation of the linac, the booster, and the storage ring from high-voltage corona and from the passage of short-wavelength x-rays through the air.

Method of Detection

Ozone is detected by sensing equipment and by observation of personnel in the affected area.

Preventive/Mitigating Features

The linac, booster, and storage-ring tunnels are ventilated to reduce the concentration of ozone. The electron-gun enclosure has a closed-circuit air-conditioning system to dehumidify the air to reduce corona. The door to the enclosure is opened for 10 minutes to allow adequate venting before entry. The ozone odor is noticeable. Open air paths for x-rays will be minimized in the photon beamlines, but there is presently no proposal for a beamline that provides for x-rays with sufficiently short wavelengths to cause an ozone problem.

Consequences

The consequence of ozone exposure is personnel injury. From Table 4-4, the consequence level is judged to be low.

Probability

Forced-air ventilation and administrative procedures reduce the probability of exposure to ozone to low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of low results in a risk of negligible.

5.9 Seismic Safety and Emergency Preparedness

5.9.1 Seismic Safety

Seismic safety is designed into the ALS technical components through the application of standard LBL design criteria or approved criteria for special structures. The seismic design criteria and installation procedures are documented in Chapter 23 Seismic Safety of the LBL Health and Safety Manual. The intent of the design criteria is to result in structures that can resist, without collapse, earthquakes of Richter magnitude 7.0 on the Hayward fault and 8.3 on the San Andreas Fault. Seismic safety is designed into components by means of static or dynamic analyses. Design criteria for the accelerator support components were developed from DOE and LBL guidelines, were reviewed by the LBL Seismic Safety Subcommittee, and are consistent with DOE Order 6430.1A. Other references include Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards [UCRL, 1989], Strong Seismic Ground Motion for Design Purposes at the Lawrence Berkeley Laboratory [Bolt, 1979], Fundamentals of Earthquake Engineering [Newmark and Rosenbluth, 1971], and Seismic Analyses of Structures and Equipment for Nuclear Power Plants [Bechtel, 1974].

Dynamic analysis was performed on the accelerator support components, which were engineered to be in compliance with the design criteria. All accelerator concrete shielding structures were engineered to be in compliance with the seismic design criteria and were reviewed by a qualified consulting engineer retained for this purpose by LBL.

The building has been designed to meet structural criteria required by the 1988 Uniform Building Code and to meet the July 1, 1985 LBL Lateral Force (Wind and Earthquake) Design Criteria. The LBL criteria for lateral loads are wind: 20 psf and earthquake: base shear equal to 0.2 W, where W = total dead load of structure plus equipment weight, as specified in Chapter 23 of the LBL Health and Safety Manual.

Earthquake-safety measures have been developed to provide safety for personnel in the event of a seismic disturbance. It is required that protection be provided to allow adequate time for personnel to exit an endangered area with a minimum of injuries. All equipment, hardware, and objects inside and outside of buildings are adequately restrained and/or anchored from toppling, sliding, rolling, walking, or falling so that equipment and hardware will not block egress paths and exit doors during seismic ground motion.

5.9.2 Emergency Preparedness

The LBL Master Emergency Plan (MEP) [LBL, 1980] developed in accordance with DOE Order 5500.3A [DOE, 1991a], addresses site-wide disasters including earthquakes. The MEP defines the elements of the emergency response organization and their capabilities. Organization and functions of the Emergency Command Center and Command Center Team are discussed. Annual emergency drills and training are required in accordance with the MEP.

The Building 6 Complex Emergency Plan is consistent with the MEP and the plan is exercised at least once annually. The Building Manager, who serves as the building-emergency team leader, is responsible for planning and coordinating emergency actions for the ALS. The ALS Building Manager works closely with the Laboratory Emergency Preparedness Coordinator to ensure emergency plans are coordinated and are consistent with lab wide plans. Emergency team members are required to participate in emergency team training, building manager orientation and must be first aid and CPR qualified.

The Building 6 Complex Emergency Plan contains the following information: how to report an emergency, responsibilities of emergency team members, categories of accidents, locations of related OSPs, emergency shut-down procedures for utilities, and evacuation maps show routes of egress and assembly areas outside the complex. Evacuation maps also designate the location of emergency equipment (see Figures 5-1 and 5-2). Light Source Procedure LSP-019 Injector Emergency-Shutdown Procedure [Massoletti, 1991] gives the appropriate actions when the decision has been made to shut down the accelerator system in the event of an emergency.

The Master Emergency Plan, Building Emergency Plan and associated training and drill program form the basis upon which the ALS earthquake and emergency preparedness is based.

A 300-kVA emergency generator has been installed to provide emergency power to critical ALS systems, including emergency lighting for exit pathways, building PA system, and fire-protection systems.

5.9.3 Seismic Safety Analysis Summary

(1) Hazard Event: Earthquake

Initiating Occurrence

Earthquakes are a natural phenomenon. The most serious event would be a large earthquake of Richter magnitude 7 or slightly larger on the Hayward fault.

Method of Detection

Noticeable ground movement is the primary means of detection.

Preventive/Mitigating Features

The building structure and equipment meet basic earthquake design criteria and applicable codes. All equipment, hardware, and objects inside and outside of buildings are restrained and/or anchored. In accordance with the LBL basic earthquake design criteria, the accelerator is bolted to withstand a 0.7 g lateral acceleration. The design allowable stress during a seismic event for structural steel members, fasteners, and anchor bolts is limited to 75% of the material ultimate strength; the stress for welds is limited to 50% of the material ultimate strength. There is an emergency power generator. The Building 6 Complex Emergency Plan is integrated into the LBL Master Emergency Plan. Administrative controls include OSPs, AHDs, LSPs, COPs, adherence to Chapter 23 Seismic Safety of the LBL Health and Safety Manual, and employee training. Medical treatment is available at LBL.

Consequences

The consequence of an earthquake occurrence is personnel injury, damage to equipment, and shutdown of the facility. From Table 4-4, the consequence level is judged to be medium.

Probability

The frequency of large earthquakes on either the Hayward or the San Andreas faults is not well known. The last large earthquake on the Hayward fault occurred more than 100 years ago. The U.S. Geological Survey predicts a major earthquake on this fault system will occur in the next 30 years with less than a 50% probability. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of low.

Risk

From the risk matrix in Table 4-6, a consequence level of low and a probability level of medium results in a risk of low.

5.10 Beamline Vacuum System Safety Analysis Summary

(1) Hazard Event: Beamline Vacuum Vessel Implosion and Explosion

Initiating Occurrence

Beamline vacuum vessels potentially can implode under vacuum (if improperly designed) or explode during venting (if overpressured). Failure of the containment wall or window of a vacuum vessel could result in injury to personnel or equipment from flying debris.

Method of Detection

Observation by personnel in the affected area is the primary means of detection of a beamline vacuum vessel implosion or explosion.

Preventive/Mitigating Features

Beamline vacuum vessels and windows on vacuum systems are designed and tested following the guidelines contained in Chapter 30 Research Equipment of the LBL Health and Safety Manual. Pressure relief valves, if needed, mitigate explosion danger. Administrative controls include review by the Beamline Review Committee, the Experimental Systems AHD, a COP for beamline venting, and employee training. Medical treatment is available at LBL.

Consequences

The consequence of accidents involving implosion or explosion of beamline vacuum vessels is severe personnel injury or damage to equipment. From Table 4-4, the consequence level is judged to be medium.

Probability

Proper design and testing of vacuum vessels and windows and use of pressure relief valves reduce the probability of accidents involving implosion or explosion of vacuum vessels to extremely low. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of extremely low.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of extremely low results in a risk of negligible.

5.11 Industrial Accident Safety Analysis Summary

(1) Hazard Event: Industrial Accident Involving Rotating Machinery or Falling Objects

Initiating Occurrence

Pumps, blowers, and fans are examples of automatic rotating machinery that are part of normal operations in the ALS building. The cavity water systems of the storage-ring rf system has high-speed, motor-driven pumps and remotely operated motorized valves for the cavity water systems; the rf-cavity-tuner drives have a high-torque, semi-open mechanism, which is servo-operated and can move without warning; the variable-voltage transformer on the exterior pad has a powerful chain-driven linear motion system with the confined VVT cabinet; and the high-voltage switches and door lock within the crowbar cabinet have powerful solenoid-operated mechanisms. The insertion-device gaps are varied by moving the backing beams, which is accomplished in turn by rotating 2-mm-pitch Transrol roller screws that are mounted to the horizontal beams and support the backing beams. Valve and shutter actuators are high-force compressed-air devices. The overhead crane hook and/or its burden can move in the ALS building, and the burden could drop to the floor.

Method of Detection

Observation by personnel in the affected area is the primary means of detection.

Preventive/Mitigating Features

During operation, guards must be in place on fans and pump-motor shafts, and signs warning of automatic equipment startup are posted. Before beginning work on a pump, it will be switched off and locked out at the exterior pump breaker in accordance with lockout-tagout procedures as Chapter 8 Electrical Safety of the LBL Health and Safety Manual and ALS 09-01 Electrical Logout/Tagout (LOTO) Supplemental Procedure for the ALS . Before operating the cavity-tuner drives, they must be checked to assure that the guard plates are in position and that no cables become entangled in the mechanism. During crane operation, the active area is designated as a hard-hat area and non-essential personnel are moved away. Crane operation is in accordance with Chapter 17 Materials Handling and Storage of the LBL Health and Safety Manual. Crane operators are trained and certified. Medical treatment is available at LBL.

Consequences

Consequences of accidents involving rotating machinery or falling objects include personnel injury and potential equipment loss. From Table 4-4, the consequence level is judged to be low.

Probability

Use of guards on rotating machinery, adherence to lockout/tagout procedures, and use of hardhats reduces the probability of accidents involving rotating machinery or falling objects to medium. From Table 4-5, the Technical Safety Subcommittee assigned a probability level of medium.

Risk

From the risk matrix in Table 4-6, a consequence level of medium and a probability level of low results in a risk of low.

5.12 Conclusions

Operational activities planned for the ALS facility have been analyzed for hazard potential, and appropriate mitigation measures have been developed. The hazards analysis identified potentially hazardous conditions that could occur in the ALS during operations. Control measures were incorporated into the facility and systems design to mitigate most of the identified potential hazards. In other cases, administrative procedures were developed to ensure that facility operations could be conducted with a minimum of on-site and off-site consequences.

A risk analysis on 19 categories of credible hazard events for hazards other than ionizing radiation, was performed using a bounding event/worst-case approach. Table 5-4 summarizes the results of the risk analysis. Combined with the risk analysis for ionizing-radiation hazards summarized in Table 4-7, these results show that the ALS facility will be operated within the risk envelope for low-hazard facilities as defined in SAN Management Directive 5481.1A.

Table 5-4. ALS Risk-Determination Summary.

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
Fire Hazards				
1	Room Fire	Low	Low	Negligible
2	Room Fire Involving Radioactive or Toxic Materials	Low	Medium	Low
3	Equipment Fire	Medium	Low	Low

Table 5-4. ALS Risk-Determination Summary (cont.).

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
Hazardous Materials				
1	Uncontrolled Chemical Reactions	Extremely Low	Extremely Low	Negligible
2	Chemical Exposure	Medium	Low	Low
3	Cryogenic Temperature Exposure	Medium	Low	Low
4	Compressed Gas Explosion	Low	Medium	Low
5	Gas Explosion (Hydrogen, Oxygen, Acetylene)	Low	Medium	Low
6	Inhalation, Ingestion, or Dermal Exposure to Toxic or Carcinogenic Material	Extremely Low	Medium	Negligible
7	Oxygen Deficient Atmosphere	Extremely Low	Medium	Negligible
Electrical Hazards				
1	Electrical Shock	Low	Medium	Low
2	Nonionizing Radiation Exposure	Low	Medium	Low
3	Exposure to High Magnetic Forces	Medium	Low	Low
Laser Hazard				
1	Laser Light Energy Transfer	Low	Low	Negligible

Table 5-4. ALS Risk-Determination Summary (cont.).

No.	Hazard Event	Probability Level	Consequence Level	Risk Level
Visible and Near-UV Light Hazard				
1	Exposure to Visible and Near-UV Light	Low	Low	Negligible
Ozone Hazard				
1	Ozone Exposure	Low	Low	Negligible
Seismic Hazard				
1	Earthquake	Low	Medium	Low
Vacuum Vessel Hazard				
1	Beamline Vacuum Vessel Implosion or Explosion	Extremely Low	Medium	Negligible
Industrial Accident				
1	Industrial Accident Involving Rotating Machinery or Falling Objects	Medium	Low	Low

SECTION 6. SAFETY ENVELOPE

The Safety Envelope is a set of physical and administrative conditions based on environment, health, and safety (EH&S) considerations that are contained in DOE Order 5480.25 Safety of Accelerator Facilities [DOE, 1992] and that establish and define the boundaries within which an accelerator and its experiments may be operated. If all operations are performed within the boundaries of the Safety Envelope, the facility staff, the facility users, the general public, and the environment will be protected. Variations in operating conditions are permitted if and only if their extent, duration, and consequences do not exceed the bounds imposed by the Safety Envelope. Within its Safety Envelope, for example, an accelerator facility can experience unplanned events, such as an unscheduled power outage, that may interrupt its operation but do not compromise the safety of the facility. The Safety Envelope should not be violated by the effects of such unscheduled, but anticipated, events of no EH&S consequence. Variations beyond the boundaries of the Safety Envelope are treated as reportable occurrences, as defined by DOE Order 5000.3A Occurrence Reporting and Processing of Operations Information [DOE, 1991b].

The basis of the Safety Envelope presented here is the safety analysis described in Sections 4 and 5. The Safety Envelope is documented to define physical conditions and administrative controls that ensure safe operation of the ALS accelerator complex and the beamline and experimental areas within the envelope of the accident scenarios identified for the facility. The requirements specified in the Safety Envelope are binding for operation of the ALS. Significant revisions of these requirements, changes in operating conditions, or any facility and/or equipment modifications that involve an unreviewed EH&S issue will require a revision or supplement to this FSAD. The Safety Envelope covers both technical and administrative matters. Requirements in the Safety Envelope related to technical matters address those facility features of controlling importance to EH&S. Requirements in the Safety Envelope related to administrative matters include those that are important to establishing safe operating conditions in the facility. Nothing in the Safety Envelope will restrict changes in organizational titles or organizational assignments within these requirements if equivalent functions are provided.

Facility operations routinely takes place with variability in the numerous parameters characterizing its performance. Accordingly, an Operations Envelope is used to provide assurance that the Safety Envelope is not exceeded as the operating parameters change. By defining the limits beyond which the operating parameters would require corrective actions to be taken, the Operations Envelope serves as a form of administrative control to provide assurance that the Safety Envelope is not exceeded. Variations of operating parameters within the Operations Envelope are normal. Variation of operating parameters outside the Operations Envelope but within the Safety Envelope are not treated as an occurrence requiring reporting under DOE Order 5000.3A but can cause administrative actions to be taken by the facility management.

Maintenance, inspection, and surveillance of all facility EH&S systems are assured by appropriate OSPs, AHDs, and procedures, as provided for in Section 6.5.

Operations and Safety Envelopes for accelerators, beamlines, and experiments are discussed separately in Sections 6.2, 6.3, and 6.4, respectively. The separate requirements of the accelerators, beamlines, and experiments Safety Envelopes are integrated in Table 6-1 and comprise the ALS Safety Envelope:

Table 6-1. Safety Envelope for ALS Accelerators, Beamlines, and Experiments

- Linac beam power: any combination of beam current, energy, and cycle rate that gives a beam power of 0.85 W (e.g., for the nominal operating parameters of 2 x 10^{10} electrons/cycle, 50-MeV electron energy, and 1-Hz cycle rate, the beam power is 0.16 W).

- Booster synchrotron beam power: any combination of beam current, electron energy, and cycle rate that gives a beam power of 8.25 W (e.g., for the nominal operating parameters of 16 mA or 2.6 x 10^{10} electrons accelerated and extracted/cycle, 1.5-GeV extracted beam energy, and 1-Hz cycle rate, the beam power is 6.2 W).

- Energy in storage-ring beam: any combination of stored current and electron energy that gives a total energy of 1000 J (e.g., for the nominal operating parameters of 400-mA stored current or 1.65 x 10^{12} electrons and 1.5-GeV electron energy, the energy in the beam is 395 J).

- A search-and-secure is carried out for each High Radiation Area (in which there is the potential for a whole body dose of 1 rem in any one hour) in the ALS building to assure that all personnel are excluded.

- At least one accelerator operator is on shift during accelerator operation.

- The personnel safety shutters that are an integral part of the bremsstrahlung collimation system or bremsstrahlung shield are closed during injection of beam into the storage ring.

- The bremsstrahlung shielding and exclusion zones are in place.

- In beamline areas, the VUV and soft x-ray radiation is contained within vacuum tubes and chambers.

- In experimental areas, the VUV and soft x-ray radiation is contained within vacuum chambers or within an interlocked hutch.

- Quantities of hazardous chemicals and materials in the ALS building do not exceed the 1988 UBC/UFC B-2 Exempt Aggregate Quantity per Control Area listed in Table 5-3.

6.1 Operational Procedures

The ALS is committed to the highest level of quality in all its activities. In this context, quality encompasses successful achievement of operational goals, environmentally responsible operation, and, above all, safety. Facility operations are specifically intended to be in compliance with DOE Order 5480.19 Conduct of Operations Requirements for DOE Facilities [DOE, 1990b], including Attachment I Guidance for the

Conduct of Operations at DOE Facilities. The ALS Group Guidelines for Conduct of Operations [ALS, 1990b] and the ALS Accelerator Conduct of Operations document [Jackson, 1992b] applies DOE Order 5480.19 to the specific situations encountered in ALS operations.

Assurance of safe conduct of operations within the boundaries of the Safety Envelope relies in part on Operational Procedures, which are written documents providing specific direction for operating systems and equipment during normal and postulated abnormal and emergency conditions. Within the context of the ALS, at the time this FSAD was prepared there were five types of Operational Procedures applicable to ALS activities: Activity Hazard Documents (AHDs), Operational Safety Procedures (OSPs), Light Source Procedures (LSPs), Conduct of Operations Procedures (COPs), and Specific Safety Procures (SSPs). Appendix 1 lists the Operational Procedures in existence at the time this FSAD was prepared.

AHDs are required by Chapter 1 (Appendix B) of the LBL Health and Safety Manual [LBL, 1992a] for all operations where a significant potential health, safety, or environmental hazard can be identified. AHDs perform a function similar to that of the former OSPs, which are no longer generated. During the preparation of AHDs (or, formerly, OSPs), potential hazards are identified, mitigation measures developed, and specific controls established for the conduct of the proposed operations. Mitigation and control measures developed are based on ALARA guidelines provided in Chapter 21 of the LBL Health and Safety Manual. For the ALS facility, AHDs (or, formerly, OSPs) are prepared by the cognizant operations staff, scientific staff and/or lead engineers involved in the proposed operation and are approved by ALS management, the ALS EH&S Group, and the Accelerator and Fusion Research Division Director. The LBL Environment, Health, and Safety Division provides guidance for the preparation of AHDs (or, formerly, OSPs) and must review the draft document prior to approval.

LSPs for all anticipated operations, tests, and abnormal or emergency situations have been developed by the cognizant operations staff, scientific staff, and/or lead engineers involved in the proposed operations. Approval of a proposed procedure is at a level commensurate with the consequences of accidents, failure, or other abnormal conditions in accordance with the provisions of LSP-008 Light Source Procedure Document Control [Jackson, 1991a]. The procedures provide administrative and technical direction to execute the procedure effectively. The extent of detail in a procedure depends on the complexity of the task, the experience and training of the operator(s) and user(s), the frequency of performance, and the significance of the consequences of error.

LSPs were initially developed primarily by the Accelerator Group. At the time this FSAD was prepared, a broader procedure category covering all types of ALS technical and administrative operations was in effect called Conduct of Operations Procedures. In particular, as LSPs become obsolete, they are replaced by COPs. Guidelines for preparation and approval of COPS are provided in ALS 16-01 Advanced Light Source Center Procedure Format and Guidelines [Jones, 1993e]. ALS 16-01 also provides for training of ALS staff in procedures appropriate to the staff member's job, as described in ALS 01-01 Training Documentation for Procedures [Jones, 1993f]. The ALS EH&S Group Administrator is responsible for maintenance of all procedures.

SSPs are required by Chapter C of the LBL Chemical Hygiene and Safety Plan [LBL, 1992c] for all operations that involve the use of hazardous materials and whose consequences are not sufficiently severe to warrant the preparation of an AHD. SSPs are written safety procedures that indicate specific measures that will ensure worker safety. The cognizant operations staff, scientific staff, and/or lead engineers involved in the proposed operations has the responsibility of preparing SSPs that describe (1) the specific hazards associated with a procedure or operation, and (2) the methods (i.e., safety procedures) for controlling those hazards. SSPs are to be followed by all personnel performing the specific tasks or operations for which they are written. SSPs are intended as internal documents and are not required to be reviewed outside the originating organization. Each SSP is reviewed by the cognizant staff member or supervisor at least annually.

6.2 Accelerators

6.2.1 Accelerator Systems

For the purposes of this FSAD, the ALS accelerator systems include the injector complex (50-MeV electron linear accelerator; 1.5-GeV, 1-Hz booster synchrotron; and transfer lines), and the electron storage ring (operating range from 1.0 to 1.9 GeV), but not the insertion-device synchrotron radiation sources in the straight sections of the storage ring (maximum of 10 insertion devices) or the bend-magnet synchrotron-radiation sources in the curved arcs of the storage ring (maximum of 48 bend-magnet ports). At the time this FSAD was prepared, the commissioning of the injector system under the PSAD [ALS, 1990c] had proceeded to the point that the injector was robust and performed to design specifications. Storage-ring commissioning under Revision 1 of this FSAD had proceeded to the point that the storage ring met its design goals for energy and current. Additional commissioning with insertion devices installed was required. The degree of documentation for these systems varied accordingly.

6.2.2 Accelerator Operations Envelope

Operation within the Operations Envelope for accelerators is guaranteed primarily by Operational Procedures, by the safety systems designed into the ALS accelerator systems, and by the administrative procedures that regulate operations of the accelerator systems.

The accelerator systems are designed to operate safely and without harming the environment, not only under the standard set of operating conditions, but also under unusual operating conditions that might be encountered during the commissioning of new and novel facility enhancements. The parameters that specify these operating conditions are the injection scenarios, the beam energy, the beam current, and the beam power. Table 6-2 summarizes the values of these parameters and operating ranges that are permitted within the Operations Envelope.

Table 6-2. *Operations Envelope for the ALS accelerator systems.*

- Linac beam power: any combination of beam current, energy, and cycle rate that does not exceed a beam power of 0.3 W.
- Booster energy will not exceed the limits of 50 to 1500 MeV (ramped).
- Booster current will not exceed 16 mA.
- Storage ring energy will be from 1000 to 1900 MeV (1500 MeV nominal).
- Storage ring current will not exceed 500 mA.
- Operation is guided by the ALS Accelerator System Activity Hazard Document and references therein.
- Magnetic-field and rf/microwave-radiation intensities comply with Threshold Limit Values (TLVs) established by the American Conference of Government Industrial Hygienists.
- Operations is guided by the ALS Accelerator Conduct of Operations and references therein.
- All entrances to the ALS experimental-area floor are locked and posted as a Controlled Area; access is restricted to authorized personnel.
- The integrity of the accelerator and safety systems is verified by inspection tours and by adherence to maintenance schedules, as specified in Operational Procedures.
- The requirements of the Beamlines Operations Envelope and the Experiments Operations Envelope are met.

Additional discussion of Operational Procedures for accelerators appear below throughout Section 6.2. Maintenance, inspection, and surveillance of safety systems and staff EH&S training are discussed in Sections 6.5 and 6.6, respectively. Reference to procedures is also made in Sections 4 and 5.

6.2.3 Accelerator Safety Envelope

The Safety Envelope for accelerator operations emphasizes, but is not limited to, the primary accelerator operating parameters, which directly affect the production of and exposure to ionizing radiation. The values of the operating parameters are chosen to meet the design goals of limiting the radiation exposure to the general public to less than 10 mrem/year (0.1 mSv/year) and limiting occupational exposure to laboratory workers to less than 250 mrem/2000-hour worker year (2.5 mSv/year) and to 1 rem/9000-hour worker year (10 mSv/year), as well as the design goals for continuous occupancy of 0.5 mrem/hour (5 μSv/hour) and for a single event of 40 mrem.

Day-to-day accelerator operations will be guided by the requirements contained in the Operations Envelope described in the previous section and by the documents referenced in the Operations Envelope. Deviations from these requirements will cause administrative action by ALS management but will not be automatically considered as reportable occurrences under DOE Order 5000.3A until further investigation in accordance with the order indicates that the deviations are reportable. Deviations that violate the Safety Envelope will be reported as occurrences in accordance with DOE Order 5000.3A.

The Safety Envelope for accelerator operations therefore comprises the following maximum allowed values of the primary accelerator operating parameters:

- Linac beam power: any combination of beam current, energy, and cycle rate that gives a beam power of 0.85 W (e.g., for the nominal operating parameters of 2 x 10^{10} electrons/cycle, 50 MeV electron energy, and 1 Hz cycle rate, the beam power is 0.16 W).

- Booster synchrotron beam power: any combination of beam current, electron energy, and cycle rate that gives a beam power of 8.25 W (e.g., for the nominal operating parameters of 16 mA or 2.6 x 10^{10} electrons accelerated and extracted/cycle, 1.5 GeV extracted beam energy, and 1 Hz cycle rate, the beam power is 6.2 W).

- Energy in storage-ring beam: any combination of stored current and electron energy that gives a total energy of 1000 J (e.g., for the nominal operating parameters of 400-mA stored current or 1.65 x 10^{12} electrons and 1.5-GeV electron energy, the energy in the beam is 395 J).

and the following operating requirements:

- A search-and-secure is carried out for each High Radiation Area in the ALS building (in which there is the potential for a whole body dose of 1 rem in any one hour) to assure that all personnel are excluded.
- At least one accelerator operator is on shift during accelerator operation.

6.2.4 Operational Procedures

Accelerator operations are guided by the ALS accelerator Conduct of Operations document. The ALS accelerator Conduct of Operations document applies the ALS Group Guidelines for Conduct of Operations and DOE Order 5480.19 to the specific situations encountered in ALS accelerator operations.

The ALS Accelerator Conduct of Operations document emphasizes the importance of Operational Procedures for operations. The formal requirements for preparation of Light Source Procedures are themselves the subject of LSP-008. The purpose of this procedure is to ensure that only the most current documentation is used in the workplace. The procedure describes rigorous standards regarding identification, layout, page numbering, review, approval, distribution, changes, and cancellation for all LSPs. The basic steps in generating an approved procedure are (1) the cognizant scientist or engineers develops the proposed procedure; (2) the supervisor concurs upon demonstration of satisfactory functionality of the procedure; (3) the procedure is reviewed by the appropriate ALS staff, ALS committee, or LBL committee; (4) the procedure is approved by, as appropriate, the ALS Director, the Deputy Director, or a Group Head. Approved procedures are reviewed at specified intervals. EH&S-related procedures must be reviewed at least annually, as required by Chapter 1, Appendix B of the LBL Health and Safety Manual.

The requirements for the preparation of Conduct of Operations procedures is described in ALS 16-01. The content of the procedure parallels that of LSP-008 with some differences in detail, such as the procedure format. The steps in the review and approval process are (1) the draft procedure is completed by the originator; (2) the approving official designates three knowledgeable reviewers; and (3) the procedure is approved by the most senior line manager with knowledge the day-to-day operations regarding the activities described in the procedure. The approver determines the review schedule, which is not to exceed three years from the initial approval or most recent review. However, all procedures are seen as living documents that are to be revised and updated as the need arises, including changes, additions, or deletions to the procedure.

6.2.5 Accelerator Operational Safety Procedure

An Accelerator OSP for the entire accelerator system has been developed by the Accelerator Group [Massoletti, 1992c]. Subject to revision as circumstances warrant, the OSP covers operation of the injector complex (linac and booster synchrotron) and the storage ring. The OSP is also reviewed annually and will converted to an AHD at the next scheduled revision.

The Accelerator OSP describes the controls and procedures necessary for safe commissioning, operation, maintenance, and trouble-shooting of the ALS injector complex, the storage ring, and their subsystems. The OSP identifies the hazards associated with the components of the facility and the controls that have been implemented to assure that all operations are conducted in a manner consistent with the safety of environment, personnel, and equipment in accordance with the provisions of the LBL Health and Safety Manual. Both the general policies and specific procedures referred to in the OSP have been devised with these goals in mind. In addition, the OSP emphasizes that the existence of detailed and documented procedures does not remove the responsibility of any individual recognizing a hazardous situation to take immediate corrective action and/or to notify the appropriate responsible person and his immediate supervisor.

The OSP does not itself describe detailed procedures for the operations to which it is applicable. Rather, the OSP identifies the operation, hazards, mitigating factors, and requirements, but refers to a LSP, a relevant chapter of the LBL Health and Safety Manual, or other documents for implementation. For example, as one control for ionizing radiation in the experimental area, the OSP requires that "Active radiation monitors in the experimental area are part of the interlock chain...In addition, measurements will be taken in accordance with Accelerator Initial-Operation Radiation Safety Check List, LSP-023."

Specific hazards identified in the OSP include electrical (high-voltage power supplies and high-power RF systems), radiation (x-rays from the electron gun, bremsstrahlung and neutrons from the linac, booster, and storage ring, air activation, component activation, and radioactive sealed sources), interlock chain bypass (unintentional circumvention and chain failure), rotating machinery (pumps, blowers, and fans and remotely actuated high-torque mechanisms), high-pressure water and air, hot water (hot-water pipes), toxic materials, ozone (linac and booster high-voltage corona), magnetic field (pulsed and DC fields from accelerator and transport magnets), confined space (oxygen deficiency, liquid nitrogen release, or flammable or toxic gases in accelerator cave and tunnels),implosions and explosions (vacuum failure or high-power rf devices) overhead crane (injury to personnel and damage to equipment), seismic events (seismic disturbance of accelerator structures and concrete shielding blocks), fire (accelerator cave and tunnels and oil-filled transformers).

The OSP also contains prescriptions for maintenance (inspection and testing), for operator training (see Section 6.6), and for emergency shut-down and evacuation.

6.2.6 Operations Log

In accordance with the requirements of DOE Orders 5480.19 and 5480.25 and with LBL policy stated in Chapter 1 of the LBL Health and Safety Manual, the purpose of keeping an ALS Operations Log is to maintain a complete record of events concerning the operation of the facility. Entries are made in the Operations Log for those activities that occur in or about the facility, both routine operational events and data and any abnormal occurrences. In addition, all significant events affecting operations are recorded in a timely manner.

LSP-030 Accelerator Operations Log Keeping [Brokloff, 1992] regulates operations log-keeping. Topics covered in LSP-030 include:

- Format of entries
- Required entries
- Use of highlighting
- Log archive
- Required reading and verification
- Fault reporting
- Procedure performance verification (startup and shutdown).

To facilitate the recording of sign-off requirements and compliance with the procedures for standard operations, LSP-030 provides for the use of start-up and shut-down check lists that cover (in the case of startup) startup preparation, procedures performed prior to turn-on, turn-on, and shift-manager verification and (in the case of shutdown) shutdown procedures performed, removal of access barriers, facility tour, and shift-manager verification (see Figures 6-1 and 6-2).

6.3 Beamlines

6.3.1 Types of Beamlines

For the purpose of this section, a beamline comprises the radiation source (insertion device or bend magnet), the front end, and one or more branch lines up to the

Shift Manager ____________________

On-Shift ____________________

____

Startup Preparation (Initial)

Vacuum status in log ☐ Ln fan/BR fans on. ☐

Access panels, Linac/Booster roof barriers/plugs and BTS area barriers in position as required. ☐

BTS Block positioned on the template. ☐ ☐ Verified

All Radiation Safety Interlock racks/panels closed and locked. ☐ ☐ Verified

Procedures performed (Initial)

Electron Gun Enclosure Securing ☐

Booster Magnet Turn On ☐

Booster RF Power Systems Operation ☐

Injector Administrative Search & Secure ☐ ☐ ☐

Linac/Booster Gates Functional ☐

SearchSecure of Bldg 6 Controlled Area ☐ ☐ ☐

Booster Kicker Magnet Operation ☐

Turn On (Initial)

Verified EG HV setting is at 120 KV. ☐

Ready for beam. ____________________ (Signature)

Beam On ☐

EG HV drain current at the power supply. ☐ milli-amps.

Shift Manager Verification (Initial) ☐

LSP-030

Figure 6-1. Signature block in Operations Log for accelerator startup.

Shutdown (Initial)	LSP-030
ACL Save file name, if any, recorded in log.	☐
Linac key and Booster keys switched off.	☐
Procedures performed	
Booster Kicker Magnet Operating Procedure	☐
Booster Magnet Turn On, Turn Off Procedure	☐
Booster RF Power Systems Operating Procedure	☐
Barriers to free access of tunnels and restricted areas removed.	☐
Toured facilities. check for abnormal conditions.	☐
Vacuum system checked and print-out of vacuum system status inserted in Log.	☐
Shift Manager Verification (Initial)	☐

Figure 6-2. Signature block in Operations Log for accelerator shutdown.

experimental chamber. Beamlines can be categorized in several ways. First, beamlines can be illuminated by undulators, wigglers, or bend magnets, the radiation source effecting the details of the beamline design. Second, beamlines can be designed and constructed by the ALS staff; beamlines can be designed and constructed by participating research teams (PRTs); or beamlines can be joint ALS-PRT undertakings with separate responsibility for different beamline systems (e.g., front end or branch line) or for different aspects (e.g., design, construction, or funding). Finally, beamlines differ according to the photon-energy range they service, the principal division coming between beamlines with grating monochromators at lower photon energies and those with crystal monochromators at higher photon energies.

The EH&S considerations for the various types of beamlines are essentially identical, and, for the purposes of this FSAD, a single Safety Envelope is sufficient to establish and define the boundaries within which all beamlines may be operated. The Safety Envelope for experimental chambers is discussed separately in Section 6.4. In the event that future beamlines with special requirements are proposed that result in an unresolved EH&S issue, modifications or addenda to this FSAD will be required.

6.3.2 Beamlines Operations Envelope

Operation within the Operations Envelope for beamlines is guaranteed primarily by Operational Procedures, by the EH&S systems designed into the beamlines, and by the administrative procedures that constitute the proposal submission and approval process and that regulate operations of the ALS beamlines. The ALS User Plan [Schlachter, 1992] provides the basic guidance for assurance of beamline EH&S. This plan has been developed in consultation with the ALS user community, principally through the ALS Users' Executive Committee and spokespersons for Participating Research Teams, beginning with an ALS User Safety Workshop that was held in November 1991.

The Operations Envelope for ALS beamlines is defined by the following set of requirements:

- Beamline design, construction, and installation has passed Beamline Design and Operational Readiness Reviews.

- Approved Experiment Forms for all experiments on a beamline are posted at the beamline.
- The integrity of the beamline and safety systems is verified by inspection tours and by adherence to maintenance schedules, as specified in Operational Procedures.
- The branch-line personnel safety shutters are in place, are operable, and during injection are closed.
- An Operational Procedure specific to each beamline is complete.
- The LBL Health and Safety Manual, the Light Source Procedures, and the Conduct of Operations Procedures applicable to the beamlines are adhered to in all normal, abnormal, and emergency situations.
- The requirements of the Accelerator Operations Envelope and Experiments Operations Envelope are met.
- Viewports and windows through which visible or near-UV could be transmitted are covered by an opaque cover with a warning of the hazard.

Additional discussion of elements of the Beamline Operations Envelope appears below throughout Section 6.3. Control of hazardous materials is discussed in Section 6.5.

6.3.3 Beamlines Safety Envelope

The Safety Envelope for beamline operations is deliberately confined to the production of and exposure to ionizing radiation. Radiation levels must not exceed the design goals of limiting the radiation exposure to the general public to less than 10 mrem/year (0.1 mSv/year) and limiting occupational exposure to laboratory workers to less than 250 mrem/2000-hour worker year (2.5 mSv/year) and to 1 rem/9000-hour worker year (10 mSv/year), as well as the design goals for continuous occupancy of 0.5 mrem/hour (5 μSv/hour) and for a single worst-case event of 40 mrem.

Day-to-day beamline operations will be guided by the requirements contained in the Operations Envelope described in the previous section and by the documents referenced in the Operations Envelope. Deviations from these requirements will cause administrative action by ALS management but will not be automatically considered as reportable occurrences under DOE Order 5000.3A until further investigation in accordance with the order indicates that the deviations are reportable. Deviations that violate the Safety Envelope will be reported as occurrences in accordance with DOE Order 5000.3A.

The Safety Envelope for Beamline Operations there comprises the following:

- The personnel safety shutters that are an integral part of the bremsstrahlung collimation system or bremsstrahlung shield are closed during injection of beam into the storage ring.

- The bremsstrahlung shielding and exclusion zones are in place.

- The VUV and soft x-ray radiation is contained within vacuum tubes and chambers.

6.3.4 Beamline Design and Operational Readiness Reviews

As provided by the ALS User Plan, beamlines to be constructed by Participating Research Teams will be subject to a Beamline Design Review. The approach is similar to that at the National Synchrotron Light Source [NSLS, 1982, 1988b]. For the purposes of the review, the beamline includes, as appropriate, front ends, branch lines, and any other permanently installed optics. (In this FSAD, insertion devices are discussed as synchrotron-radiation sources in Section 6.2.7.) The beamline designer will provide such information about the beamline as is required to evaluate its design, expected performance, and EH&S features, as outlined in ALS Beamline Design Requirements [ALS, 1993a]. Appendix A of this document describes criteria for beamline bremsstrahlung shielding [Donahue, 1992c]. The information provided by the beamline designer could include, but is not limited to, drawings, radiation and shielding calculations, descriptions of interlocks, and operational procedures.

A Beamline Review Committee [ALS, 1992b] has been appointed that will be responsible for reviewing proposed beamlines for all relevant considerations, including general safety, radiation shielding, interlocks, vacuum systems, and space requirements. The committee comprises a Chair, a representative from the User Liaison Group, the ALS EH&S Group, the Experimental Systems Group Leader, the Head of the Beamline Operations Section, a beamline coordinator from the Experimental Systems Group, the ALS Q/A Officer, and a vacuum engineer from the ALS Mechanical Group. In addition to these permanent members, there are *ad hoc* members for radiation safety, fire safety, mechanical engineering, electrical engineering, and interlocks, as well as additional beamline coordinators. In addition to the information specified above, the PRT spokesperson must submit an Experiment Form (see Section 3.5.2). During the Beamline Safety Review, all EH&S concerns specified in the Experiment Form will also be considered.

The review process will proceed in three parts. First, the beamline designer submits design documentation to the Beamline Review Committee. The committee conducts a design review based on the principles enumerated in the ALS Beamlines Design Requirements document. If the design is approved, the beamline is installed and documentation is prepared. The Committee then conducts a beamline operational readiness review. Finally, the EH&S Group tests the completed beamline for operational readiness. At each review stage, the beamline designer can rework the design or installation and submit the revised work for another review. Upon passing all review stages, the beamline is authorized for operation by the ALS Director.

Completion of the review will result in a Beamline Safety Document, which will provide the start of the beamline's permanent file. A beamline is essentially a permanent structure that can serve many experiments by, for example, exchanging the experimental chamber(s) at the end of the beamline. Exchanging experimental chambers will have minimal impact on radiation shielding, interlocks, and other permanent or semi-permanent installations. Accordingly, initially, both a Beamline Safety Document and an Experiment Form will be generated. Thereafter, the beamline will be re-reviewed only in cases of substantive change or actual revision of the beamline. An Experiment Form will, however, have to be generated for each experiment on a given beamline.

6.3.5 Experimental Systems Activity Hazard Document

At the time this FSAD was prepared, fabrication and installation of the initial beamline systems was still under way. Design, fabrication, installation, and operation of future beamlines will be ongoing activities throughout the life to the facility. However, because many beamline operations are generic and not unique to each beamline, an Experimental Systems AHD [Schlachter, 1993] has been prepared that is intended to be applicable to all beamlines. In the event that future beamlines entail significant new hazards not envisioned in the Experimental Systems AHD, either the AHD will be amended or additional AHDs prepared, and this FSAD will be modified accordingly. The AHD is reviewed annually.

The Experimental Systems AHD describes the controls and procedures necessary for safe commissioning, operation, maintenance, and trouble-shooting of the ALS Experimental Systems, which include insertion-device or bend-magnet sources of synchrotron radiation, front ends, and beamlines. The AHD identifies the hazards associated with the components of the experimental systems and the controls that have been implemented to assure that all operations are conducted in a manner consistent with the safety of environment, personnel, and equipment in accordance with the provisions of the LBL Health and Safety Manual, the Chemical Hygiene and Safety Plan, and the LBL Radiological Control Manual [LBL 1993a]. Both the general policies and specific procedures referred to in the AHD have been devised with these goals in mind. In addition, the AHD emphasizes that the existence of detailed and documented procedures does not remove the responsibility of any individual recognizing a hazardous situation to take immediate corrective action and/or to notify the appropriate responsible person and his immediate supervisor.

The AHD does not itself describe detailed procedures for the operations to which it is applicable. Rather, the AHD identifies the operation, hazards, mitigating factors, and requirements, but refers to a procedure, a relevant chapter of the LBL Health and Safety Manual, or other documents for implementation. For example, as one control for interlock chain bypasses, the AHD requires that "The handling of interlock chain bypasses requires complete documentation or approval and authorization, installation, and removal, and testing and verification, with all limitations, conditions, and requirements specified in each case, as provided for the ALS Conduct of Operations Procedure for Temporary Bypass of Personnel Protection Systems (ALS 01-02)."

Specific hazards identified in the AHD include electrical (high-voltage power supplies and electrical heating tapes),prompt radiation (VUV and x-rays from the insertion-device and bend-magnet synchrotron-radiation sources and bremsstrahlung and neutrons from the storage ring), beamline radiation shielding and exclusion zones, experimental station radiation hutches (exposure of experimenter to radiation), interlock chain bypass (unintentional circumvention and chain failure), rotating machinery (pumps, blowers, and fans and remotely actuated high-torque mechanisms), high-pressure water and air, hot surfaces, visible light, ozone (passage of x-rays through air), magnetic field (insertion devices), lasers (beamline alignment and interferometry), liquid nitrogen (cryogenic temperature), implosion/explosion of vacuum vessels, confined space (oxygen deficiency, liquid nitrogen release, or flammable or toxic gases in accelerator cave and tunnels),vacuum vessels (implosions and explosions, window breakage), seismic events (structural failure or movement of massive components), fire (from elsewhere in the building), toxic material (beryllium), heat from synchrotron radiation (equipment damage), lifting heavy equipment (cranes and lifting devices), and mechanical motion of evacuated components.

The AHD also contains prescriptions for maintenance (inspection and testing), for operator training (see Section 6.6), and for emergency shut-down and evacuation.

6.3.6 Vacuum Policy

The storage ring and most of the beamlines share a common vacuum and are operated under ultra-high-vacuum (UHV) conditions. To maintain an adequate electron-beam lifetime and to prevent contamination of the optical components in the beamlines, the UHV systems must remain free of hydrocarbons. The storage-ring vacuum system, consisting entirely of metal, chemically cleaned, and bakeable components, will operate at a nitrogen-equivalent pressure of 2×10^{-10} Torr without beam. The ALS goal is to operate the storage ring at a pressure of 1×10^{-9} Torr with beam.

To assure the maintenance of comparable UHV conditions in the beamlines and experimental chambers and to protect the storage-ring vacuum, the document Vacuum Policy for ALS Beam Lines and Experimental Systems [Perera, Kennedy, and Meneghetti, 1991] outlines the vacuum practices that will be permitted at the ALS. The main features of the ALS Vacuum Policy are:

- Vacuum Interlocks. Fast valve sensors are located in the beamline to protect the storage ring in the event of a beamline-vacuum failure, or vice-versa, by closing when the pressure exceeds a threshold value of 1×10^{-7} Torr. Slower-moving isolation valves follow the fast valves in closing off the affected sector. Once closed, the interlocked isolation valves can be reopened only when the pressure is below 2×10^{-9} Torr. The front end isolation valve can be reopened only by an authorized ALS staff person. User-supplied vacuum interlocks must meet ALS design specifications. Authorized ALS staff members must make and test electrical connections between user interlocks and front-end components.

- Beamline Vacuum Systems: ALS beamlines are required to have all-metal, hydrocarbon-free components in the front end and satisfy UHV design criteria downstream of the front end if there is a common vacuum. Components must be inspected and leak tested after fabrication. Oil diffusion pumps are not permitted, except in experimental chambers under prescribed safeguarded conditions.

- Vacuum Design Review: Participating Research Teams responsible for building beamlines are required to submit beamline assembly drawings, a list of construction materials, and a gas burden budget for review as part of the Beamline Design Review process before ordering non-standard equipment and before fabrication of beamline components.

- Performance Tests: Conditions to be met before opening the front end isolation valve and requirements to be satisfied before an experiment can begin are prescribed.

- Experimental Chambers: End stations generally operate under UHV conditions similar to those in the beamline and the storage ring and follow similar vacuum requirements and interlock procedures. In the event that the experimental chamber is not to be maintained in UHV conditions, a window capable of withstanding at least 1 ATM pressure or a thin window with appropriate interlocks must isolate the storage-ring vacuum or differential pumping must be used. The ALS Beamline Review Committee must approve whichever strategy is adopted.

6.4 Experiments

6.4.1 Types of Experiments

Experiments at the ALS involve the use of VUV and soft x-ray radiation from beamlines to illuminate samples in experimental chambers. The experiments described in Section 3 and covered by the Safety Analysis in Sections 4 and 5 fall roughly into two general categories: (1) those in which there is no solid window between the beamline and the experimental chamber, so that radiation is entirely contained at all times within the stainless-steel walls of the beamline and experimental chamber, and (2) those in which there is a window between the beamline and the experimental chamber, so that in some experiments the radiation may pass through air and is not entirely contained within the walls of the beamline and the experimental chamber.

Experiments may also be conceptually categorized as PRT experiments and independent-investigator experiments. PRT experiments involve the construction and operation of beamlines, as well as experimental chambers. The beamline and experimental chamber are quasi-permanent in nature, but the experimental investigations change with time. Independent-investigator experiments may involve bringing experimental chambers to the ALS from other locations or they may involve use of chambers provided by the ALS facility or by PRTs [ALS, 1992a], and they are transient in nature with a typical experiment lasting two weeks. Detailed discussion of ALS user types may be found in User Policy at the Advanced Light Source [ALS, 1988c].

The EH&S considerations for the various types of experiments differ somewhat. For example, a beamline delivering high-photon-energy x-rays to an experimental chamber in which the x-rays pass through air for some distance would have an interlocked hutch that would prevent access to the experimental chamber when the beam was on. For the purposes of this FSAD, however, a single Safety Envelope is sufficient to establish and define the boundaries within which all experiments may be operated. The Safety Envelope for beamlines is discussed separately in Section 6.3. In the event that future experiments with special requirements (such as containment facilities for radioactive isotopes or for biological hazards) are proposed that result in an unresolved EH&S issue, modifications or addenda to this FSAD will be required.

6.4.2 Experiments Operations Envelope

The Operations Envelope for experiments is defined primarily by Operational Procedures, by the EH&S features designed into the experimental chambers, and by the administrative procedures that constitute the proposal submission and approval process and that regulate operations on the ALS experimental floor. The ALS User Plan provides the basic guidance for assurance of experimental EH&S. This plan has been developed in consultation with the ALS user community, principally through the ALS Users' Executive Committee and spokespersons for Participating Research Teams, beginning with an ALS User Safety Workshop that was held in November 1991.

The Operations Envelope for ALS experiments is defined by the following set of requirements:

- Approved Final Experiment Safety Review forms and applicable OSPs for all active experiments at an experimental station are posted.

- Each experimenter has received ALS EH&S training

- The integrity of the experimental, vacuum, and safety systems is verified by inspection tours at the beginning of each unit of beamtime and before the beamline is brought from off-line to on-line.

- All required radiation safety protective interlock systems are tested according to the approved schedule and are operating to prevent access to excluded areas by experimenters.

- Hazardous chemicals are stored in approved cabinets or are used in limited, controlled quantities appropriate for a B-2 occupancy and for the approved purpose.

- Viewports and windows through which visible or near-UV could be transmitted are covered by an opaque cover with a warning of the hazard.

- The LBL Health and Safety Manual, the Light Source Procedures, and the Conduct of Operations Procedures applicable to the experiments are adhered to in all normal, abnormal, and emergency situations.

- The requirements of the Accelerator Operations Envelope and Beamlines Operations Envelope are met.

Additional discussion of elements of the Experiments Operations Envelope appears below throughout Section 6.4. Control of hazardous materials is discussed in Section 6.5.

6.4.3 Experiments Safety Envelope

The Safety Envelope for experiment operations is deliberately confined to the production of and exposure to ionizing radiation and to use of and exposure to hazardous chemicals and materials. Radiation levels must not exceed the design goals of limiting the radiation exposure to the general public to less than 10 mrem/year (0.1 mSv/year) and limiting occupational exposure to laboratory workers to less than 250 mrem/2000-hour worker year (2.5 mSv/year) and to 1 rem/9000-hour worker year (10 mSv/year), as well as the design goals for continuous occupancy of 0.5 mrem/hour (5 μSv/hour) and for a single worst-case event of 40 mrem.

Day-to-day experiment operations will be guided by the requirements contained in the Operations Envelope described in the previous section and by the documents referenced in the Operations Envelope. Deviations from these requirements will cause administrative action by ALS management but will not be automatically considered as reportable occurrences under DOE Order 5000.3A until further investigation in accordance with the order indicates that the deviations are reportable. Deviations that violate the Safety Envelope will be reported as occurrences in accordance with DOE Order 5000.3A.

The Safety Envelope for Experiments therefore comprises the following:

- The VUV and soft x-ray radiation is contained within vacuum chambers or within an interlocked hutch.

- Quantities of hazardous chemicals and materials in the ALS building do not exceed the 1988 UBC/UFC B-2 Exempt Aggregate Quantity per Control Area listed in Table 5-3 of the FSAD.

6.4.4 Experiments Safety Review

As provided for in the ALS User Plan and Conduct of Operations Procedure US 02-03 Experiment Form Review for Advanced Light Source Users [Perdue, 1993b], the spokesperson for each approved experiment must complete an Experiment Form. The completed Experiment Form will be reviewed by the Head of the User Liaison Group and the ALS EH&S Group. Their review may trigger additional actions, including reviews by the Experimental Systems Group, the Electrical Group, the Mechanical Group, and groups within the Environment, Health, and Safety Division, as appropriate. In some cases, the experimenter-in-charge may have to provide additional information, such as circuit diagrams for home-made electrical apparatus. or take other actions that will be specified on an Action List provided to the experimenter. No experiment will be approved if the information submitted in the Experiment Form does not comply with applicable ALS, LBL, DOE, or other federal or state environmental, safety, and health regulations. For example, experimental chambers must have chemical hazard safeguards, such as exhaust ventilation and containment systems. For experiments that do not pass the Safety Review, the information necessary to bring the experiment into conformance, if that is possible, will be provided to the experimenter.

When an experiment has passed the review, the Head of the Beamline Operations Section will coordinate with the experimenter-in-charge concerning shipping/receiving and storage of equipment and materials. All equipment and materials brought to the ALS as part of an experiment will be subject to inspection by the ALS EH&S Group and the Operations Coordinators with cognizant engineers brought in as needed.

A one-page Experimental Modification Form will be used to described minor modifications to an already-approved Experiment Form, as described by Conduct of Operations Procedure US-02-08 Experiment Modification Form[Jones, 1993g].

The information on an approved Experiment Form will also be used to help determine the types of training required for experimenters. The ALS EH&S Group and the Training Department of the Environment, Health, and Safety Division will be responsible for establishing the need for training and for providing the training (see Section 3.5.6).

Where the information on an Experiment Form indicates there is a significant potential health, safety, or environmental hazard, an AHD will be required before approval is granted. In some cases, already existing AHDs will be applicable and a new one will not be necessary. In cases where no existing AHD is applicable, an AHD will be generated as described in Section 6.1.

No experiment will be permitted to begin until copies of an approved Experiment Summary Sheet and applicable AHDs are posted at the experimental station, as required by Conduct of Operations Procedure US-02-05 [Jones, 1993c]. To assure all potentially hazardous items and equipment are secured upon completion of an experiment, the ALS Post-Experimental Form will be used to document that the Operations Coordinator and the ALS EH&S Group have inspected and verified the securing of potentially hazardous experimental equipment, as specified in Conduct of Operations Procedure US 02-07 ALS Post-Experimental Form [Jones, 1993h].

6.4.5 Vacuum Policy

The ALS Vacuum Policy discussed in Section 6.3.6 applies to experimental chambers as well as to beamlines. In particular, before beginning an experiment, the user must demonstrate to an Operations Coordinator that all vacuum interlocks in the experimental chamber(s) perform satisfactorily, that pumps are properly vented and equipped with appropriate interlock isolation valves to protect against pressure and/or power failures, and that adequate measures have been provided to protect the storage-ring vacuum from an accidental break in the experimental-chamber vacuum system. The experimental chamber and its contents should be manufactured in conformance with guidelines presented in the ALS Vacuum Policy. In the event that the beamline and experimental chamber are not to be maintained in UHV conditions, a window capable of withstanding at least 1 ATM pressure or a thin window with appropriate interlocks must isolate the storage-ring vacuum or differential pumping must be used. The ALS Beamline Review Committee must approve whichever strategy is adopted.

Venting of vacuum pumps on the ALS experimental floor is presently being planned. A procedure will be developed for the use of the venting system to avoid unsafe conditions, such as chemical reactions in the venting system. Separate exhaust ventilation and containment will be provided where necessary in accordance with Chapter F of the LBL Chemical Hygiene and Safety Plan.

6.4.6 Operations Coordinators

Responsibility for user EH&S will reside with the ALS EH&S Group. Implementation will be coordinated with the Beamline Operations Section. The head of the Beamline Operations Section will oversee the scheduling and operations of a team of Operations Coordinators. EH&S on the ALS experimental floor will be the responsibility of the Operations Coordinators. Their training will allow them to deal with EH&S issues on the spot or to refer questions elsewhere if necessary. The Operations Coordinators will report on EH&S issues to the ALS EH&S Group. Approximately five Operations Coordinators will be required for full coverage during operation of the ALS for 21 shifts per week.

6.5. Maintenance, Inspection, and Surveillance of Safety Systems

Maintenance, inspection, and surveillance of accelerator EH&S systems is assured by the Accelerator OSP (see Section 6.1.4) and by appropriate LSPs and COPs. Maintenance, inspection, and surveillance of EH&S systems for beamlines and experiments will be assured by the Experimental Systems AHD (see Section 6.2.5) and by additional AHDs and procedures as they are prepared.

6.5.1 Radiation Monitoring

Since the accelerator beam is an intense source of secondary radiation (electromagnetic showers and neutrons), the accelerator is housed in concrete shielding with extensive interlocked radiation monitoring in the immediate vicinity. The purpose of the area-radiation-monitoring system is to provide radiation-level measurements, to generate audible and visual alarms when high radiation levels are measured, and to shut-down the accelerator when excessive levels occur. There is also a site-boundary radiation monitoring station (neutrons and photons) located 125 m south of the ALS building. LSP-023 Accelerator Initial-Operation Radiation Safety Check List [Massoletti, 1992a] defines the requirements for preparation, maintenance, distribution, and archiving of records required in radiological-monitoring and monitor-calibration programs at the ALS. LSP-037 Area Radiation Monitor Setpoint Changing Procedure [Collins, 1992c] describes responsibilities, prerequisites and requirements, and a step-by-step procedure for alteration of radiation trip levels that shut down accelerator operations. LSP-038 Area Radiation Monitor Changeout Procedure [Collins, 1992d] describes responsibilities, the administrative process, and step-by-step procedures for timely replacement of photon and neutron radiation monitors.

Complete records of radiological monitoring and area control at the ALS are required by LBL and DOE policy, in particular by LBL Administrative Memorandum, Policy and Procedure Vol. XVII, No. 31 Policy on Records for Radiological Monitoring and Area Control [Kerth, 1991]. Records will establish the identity of all individuals exposed to ionizing radiation or radioactive materials and the conditions under which these individuals were exposed to these hazards. The records include those generated by the Environmental and Safety Hazards Control Department of the Environment, Health, and Safety Division and/or those generated by personnel conducting monitoring programs.

The ALS Health Physicist is responsible for ensuring that the LBL staff and persons responsible for radiological areas are cognizant of and comply with the policies prescribed by LSP-023. Specific topics covered by this procedure include:

- Surveys (when and where)
- Survey and area-control records
- Controlled-access requirements
- Monitor-calibration and maintenance schedules
- Measurements to be made during the first injector operational tests
- Example measurements and controlled-access records.

LSP-023 provides for the performance of radiation surveys and their documentation whenever changes in ALS design or operation could change radiation levels, such as would occur with the passage of a milestone represented by the beginning of a new phase of testing. LSP-023 specifically requires and describes measurements to be made at the time of the first tests in order to verify the EH&S adequacy of the shielding that has been positioned around the accelerator and to characterize the new conditions. LSP-023 also specifies the placement of the radiation detectors and measurement intervals for monitoring during routine operation.

The fixed and portable radiation monitoring instrumentation for the ALS were selected from those commercially available and of reliable design known to be suitable to expected intensities and duty cycles at the ALS. Placement of the fixed radiation detectors was determined by consultation with Accelerator Physicists and the ALS Health Physicist. Two main criteria were used:

(1) <u>Probable areas of loss.</u> These locations help with machine tuning since minimum loss also means minimum radiation intensity.

(2) <u>Locations of personnel.</u> These locations monitor fields close to the accelerator that could affect personnel located at areas in and around the facility.

Fixed instruments are installed according to this placement plan and the manufacturer's recommendations. Since these instruments are also part of the accelerator interlock chain, they must be in place before the area they are intended to monitor can be occupied.

Fixed and portable instruments are calibrated annually according to approved procedures of the LBL Calibration Facility. These procedures comply with the manufacturer's recommendations. New instruments are also tested prior to use by the LBL Calibration Facility to assure that they operate within specifications.

LBL plans to provide gamma dosimetry in the form of either film or thermoluminescent dosimeters (TLDs) initially and ultimately switching to TLDs. TLDs have been used effectively for personal dosimetry for about 30 years. Since the discovery of this application, researchers have developed many detectors that are suitable for monitoring low-energy photon exposures from devices such as the ALS. Lithium Borate is an example of a TLD material that has radiation absorption characteristics very close to that of soft tissue. Neutron dosimetry will be provided in the form of NTA film, which is the accepted method for monitoring neutrons at DOE accelerator facilities.

6.5.2 Interlock Testing

Section 4.4 discusses the radiation-safety interlock protective system. For electrical, radiation, and fire safety, the interlock system consists of electrical and radiation safety chains and includes "crash-off" boxes and "crash-in" and "crash-out" release mechanisms on doors. The entire personnel-safety interlock system must be inspected and tested at least once every six months. Interlock checks must be performed according to Conduct of Operations Procedure EC 02-02 ALS Radiation Interlock System Testing Procedure [Ritchie, 1993].

The ALS Director or a designee is responsible for assurance of compliance with the requirements of EC 02-02. The maintenance of the Interlock Maintenance Log and the schedule for radiation-monitor calibration are subject to scheduled review by the ALS Director or a designee. The calibration of interlocked radiation monitors shall be carried out by the Environment, Health, and Safety Division, checked by the ALS Health Physicist, and, upon installation, tested by authorized personnel for radiation safety prior to operation of the accelerator. All training required for this procedure will be supervised by the cognizant engineer for radiation safety.

Topics specifically covered by EC 02-02 include:

- Booster radiation monitor interlock sub-chain tests
- Booster interlock sub-chain tests
- Linac radiation monitor interlock sub-chain tests
- Storage-ring BTS area interlock sub-chain tests
- Linac interlock chain tests
- Storage-ring rf area interlock sub-chain tests
- Storage-ring radiation monitor interlock sub-chain tests
- Storage-ring sectors 4 through 9 interlock chain tests

- Control-room fill/store- beam control interlock chain test
- Emergency gate-release system tests
- Restoring systems.

6.5.3 Interlock Bypass

Section 4.4 discusses the personnel protection (interlock) system. For electrical, radiation, and fire safety, the interlock system consists of electrical and radiation safety chains and includes "crash-off" boxes and "crash-in" and "crash-out" release mechanisms on doors. Testing and operation of a system may require the installation of circuit bypasses for equipment or radiation interlocks.

Authorized temporary bypasses of the personnel protection systems during operation of the ALS shall be installed in accordance with ALS 01-02 Procedure for Temporary Bypass of Personnel Protection Systems [Lancaster, Miller, and Ritchie, [1993] and with the provision of Chapter 8 Electrical Safety of the LBL Health and Safety Manual. ALS 01-02 covers roles and responsibilities of affected personnel, installation of a personnel safety system bypass, and removal of a bypass. (Bypassing equipment interlocks not associated with the personnel safety system is governed by EE 01-01 Equipment Interlock Bypass Procedure [Gregor, 1993]).

ALS 01-02 applies to all systems involved with personnel safety. Bypasses shall be installed only if measures implemented to insure personnel safety are not compromised and only if documented in the manner described in ALS 01-02. Prior to installation, all interlock bypasses shall have administrative authorization and technical approval by the individuals listed in ALS 01-02. The Operator-in-Charge shall coordinate all requests for system bypasses. Authority to bypass systems may be granted only after every other effort has been made to clear the problem.

ALS 01-02 provides for a quadruplicate record form, which is distributed to the EM (electrical maintenance) Interlock Bypass Binder in Building 80 Room 137, the Control Room Interlock Bypass Binder in Building 80 Room 140, the File I print indicated on the form, and the Safety Office Administrator. The form provides for information to be provided by the Operator-in-Charge, the technical approver, bypass installer and independent verifier, and bypass remover and independent verifier. The procedure also provides for the appropriate removal or annotation of the forms and annotation of the logbooks upon removal of the bypass.

The interlock system has been expanded to keep pace with the addition of new components. EC 02-02 (see the preceding Section 6.5.2) specifically requires interlock testing before the accelerator is to be operated and after modifications of the interlock chain, removal of a bypass, or replacement of a radiation monitor.

6.5.4 Controlled Access

Access to controlled areas is governed by the ALS Accelerator OSP [Massoletti, 1992b] with additional guidance provided by LSPs and COPs.

For normal operation, a search-and-secure procedure is carried out for each area to assure that all personnel are out of the interlocked area before startup or before resuming operation after a shut-down period when uncontrolled access has been permitted in accordance with Conduct of Operations Procedure OP 02-07 Accelerator Search and Secure Procedure [Daly, 1993]. For testing and commissioning, controlled access to the area inside the shielding is permitted in accordance with LSP-022 Accelerator Controlled-Access Procedure [Massoletti, 1992a].

The purpose of OP 02-07 is to prescribe the requirements and provide step-by-step procedures for the search-and-secure of the linac, booster synchrotron, and storage-ring in preparation for operation. The search-and-secure will result in checking equipment and clearing all personnel from the interlocked areas before starting the accelerators. The search-and-secure requires that an electronically supervised search of the Building 80-to-linac tunnel, linac cave, Beam Test Facility cave, booster ring, and sector 10 of the storage ring (BTS area) be made before permissives are granted to operate the electron-gun and modulator systems. The procedure also describes search-and-secure procedures for the storage ring. The specified number of authorized persons must perform the search-and-secure for each area. The procedure is written to provide for a total accelerator search-and-secure; specific areas are searched and secured using the section of OP 02-07 written for that area. Log entries required in OP 02-07 are made in accordance with LSP-030. Only qualified personnel listed in ALS 02-01 Accelerator Authorized Persons List [Jones, 1993h] are permitted to secure the shielded areas.

Access to the accelerator enclosures during testing, commissioning, and normal operation is regulated by LSP-022. Such restricted access requires shut-down of specific accelerator power systems, visual surveillance of the accelerator entrances during entrance and egress, and appropriate log entries. Additional restrictions on booster rf and storage-ring operation for access must comply with the requirements given in LSP-021 Booster RF Power Systems Operating Procedures [Taylor, 1992] and LSP-040 Storage-Ring RF Power System Operating Procedure [Taylor, 1993]. With proper performance of this procedure, operations may resume without performing an additional search-and-secure procedure.

Additional requirements for specific radiation surveys are given in LSP-023.

6.6 Staff Training

LBL policy (as outlined in Chapter 1 of the LBL Health and Safety Manual) and federal law require that LBL staff, participating guests, and visitors receive appropriate EH&S training. LBL management is responsible, through supervisors, for ensuring that employees and guests under their supervision receive this training and are thereby fully informed about possible occupational health hazards and have the information needed to work safely. It is also the responsibility of ALS management, through supervisors to identify training needs for job classifications for which they are responsible, as specified in Chapter 24 of the LBL Health and Safety Manual and as provided for in ALS Group Guidelines for Conduct of Operations.

6.6.1 ALS Training and Certification Program

The Training and Certification Program for ALS staff will include general EH&S training, job-specific EH&S training, task-specific EH&S training, and certification. Here "staff" includes operators, accelerator and experimental physicists, and others who perform tasks that are directly related to the operation of the ALS accelerators and/or experimental equipment. The goals of the training exercises are to provide the trainee with the necessary skills, knowledge, and background to carry out tasks safely, correctly, and expeditiously without the presence of a supervisor.

The first part of the Training and Certification Program consists of the required and recommended training for the various categories of ALS staff [ALS, 1990b]:

Universal ALS Training

Hazards Communication Training
Radiation Protection: Accelerators (2 hours)
Specific Building Emergency Plan

Specific Group Training

Operators and Electrical Maintenance
CPR (3 hours; 2-year certification)
First Aid (4 hours; 3-year certification)
Fire Extinguisher Training (1 hour)

Mechanical Shop / Technicians / Electrical Maintenance / Electrical Installation
Hazardous Waste Lab Generators

Administrative Employees
Using Video Display Terminals (1.5 hours)

Other training that may be required by supervisors

Incidental Crane Operation
Forklift Truck Safety (8 hours/3-year certification)
Forklift Truck Safety Recertification (1 hour)
Respirator Course
Gas Detector Instrumentation
Magnetic Block Mechanical Inspection
National Electric Code
Laser Safety (1/2 hour)
Radiation Protection Retraining - Accelerators (1 hour)
Handling Cryogenic Liquids

Training that is recommended includes:

All Employees
Earthquake Safety/Emergency Preparedness

All Shops Personnel
CPR
First Aid
Fire Extinguisher

Mechanical / Electrical Engineering / Design / Coordination Staff
Using Video Display Terminals

The second part of the ALS Training and Certification Program is a mechanism for identifying and tracking individual employees' training and assuring that training is kept up to date. An employee Safety and Training Profile has been developed for this purpose. The profile for each employee us generated by the employee and his/her supervisor working together. The profile indicates the training that is required of the employee by the supervisor, training that has been completed, training that must be completed, and expiration or retraining dates. Once the employee and the supervisor agree on the appropriate training requirements, both sign the form, which is then kept in the employee's personnel file. The profile is used and updated as part of the employee's yearly performance appraisal. In addition, the information is kept in the Accelerator and Fusion Research Division database that is used to flag employees needing new or updated training. Figure 4-3 shows a sample record from the current training database.

6.6.2 Operations Training

The third part of the ALS Training and Certification Program addresses specific operations-related (job-specific and task-specific) training. OP 05-01 Training and Certification [Jones, 1993j] describes requirements that must be met by classroom and on-shift training, including independent verification and certification and record keeping.

Training programs within the ALS will vary widely in content, format, and forum, from individual instruction about specific pieces of equipment at the job site to general presentations to large numbers of staff in a conference room or auditorium. For this reason, a graded approach to training practice and documentation is appropriate. In each category of training, an auditable set of records will be maintained, including entries in the training data base as described in Section 6.6.1, file copies of the training program, and, when appropriate, training certification forms. For some task-specific training, written examinations will be required. Some training programs, particularly those involving safety equipment, will require independent verification that the training has been completed successfully, usually by a second authorized instructor monitoring the trainee in the course of performing the assigned tasks.

6.7 ALARA

It is the policy of the Lawrence Berkeley Laboratory that exposure to ionizing radiation associated with LBL operations be As Low As Reasonably Achievable (ALARA) [EH&S, 1987; LBL, 1992a, Chapter 21; LBL, 1993a, Chapter 1]. The elements of the policy, which also forms the basis of the ALS ALARA policy, include:

- ALARA consists of those actions that are taken to keep individual and collective exposures to ionizing radiation, as well as radiation levels at the perimeter fence, below regulatory limits in any case and as far below regulatory limits and administrative control levels as possible consistent with satisfactory job completion.

- In all activities, there should be no exposure to radiation without commensurate benefits.

- Line management at all levels should emphasize to their subordinates that the basic philosophy of ALARA should be incorporated into all work practices. Written procedures should incorporate notes and suggestions to minimize radiation exposure when performing activities in which there is an opportunity for radiation exposure.

- Every employee is expected to demonstrate responsibility and accountability through an informed, disciplined and cautious attitude toward radiation and radioactivity.

- All workers should apply the basic principles of ALARA--time, distance, and shielding--to minimizing radiation exposure during their work activities.

The policy requires that each operation involving radioactive material or the production of radiation be evaluated individually to ensure that the resultant exposure is as low as is reasonably achievable. The relevant average risk to radiation workers should be no greater than the corresponding risk to workers in other industries generally considered to be safe.

ALS operations are subject to the principles of the LBL ALARA policy defined in Chapter 21 on Radiation Safety of the LBL Health and Safety Manual and applied throughout the chapter. The chapter contains sections on Protection Guides for Ionizing Radiation, Personal Radiation Monitoring, Monitoring of the Working Environment, Requirements for Off-Site Control, Exposure to Radiation in an Emergency, Accelerator Health Physics, Radioactive Materials, Documentation of ALARA Program, Emergency Procedures for Radioactive Spills, Radiation Safety Training, Internal Audits, X-Ray Safety Policy, X-Ray Machines Classifications and Specific Supplemental Requirements, and X-Ray Equipment Systems Safety Analysis Policy.

Documentation of the ALARA program is provided as follows:

- Personal dosimetry exposure reports. If a personal dosimeter exceeds 50 mrem on a monthly report, an investigation is initiated. Investigations of dosimeters exceeding 100 mrem (1 mSv) must be completed within one week.

- Hand dosimetry exposure reports. Researchers who potentially could receive hand exposures approaching 5 rem (50 mSv) per year are issued TLD hand dosimeters. Monthly reports are issued and studied by the Environment, Health, and Safety Division. When hand doses reach a level of 0.5 rem for more than one month, investigations are initiated.

- Air sampling data reports. Air samples taken within work sites are immediately scanned for radioactivity. Those samples that appear to be above the normal are recounted after 72 hours to allow for decay of radon and thoron daughters. Those samples that are still above normal are referred to the Environment, Health, and Safety Division for investigation.

- Area monitoring reports. Areas around accelerators are monitored using TLDs and film packs. These data are studied by accelerator health physicists and operations personnel at the accelerators. Results above action levels are investigated, and steps are taken to correct any problems. All such investigations must be documents, and a copy of the investigation report must be sent to the LBL Radiation Safety Subcommittee.

The LBL Radiation Control Manual amplifies Laboratory requirements for radiation control, including ALARA programs.

The Environment, Health, and Safety Division has conducted a study of the effectiveness of the LBL ALARA program for the years 1980-1986 [EH&S, 1987]. The study used four key indicators to evaluate the effectiveness of the program. These were (1) the average whole body dose equivalent to those radiation workers who received measurable doses, (2) the yearly fencepost dose equivalent at the LBL boundary along with the estimated dose equivalent to the general population, (3) the accident-free record of the x-ray safety program, and (4) extremity exposure control of radioisotope workers.

The study showed that, on all counts, LBL provided a safe work environment comparable to that in other industries that are considered to have a high degree of safety and that LBL added only about 5 percent to the natural radiation background at the site boundary.

SECTION 7. QUALITY ASSURANCE

All LBL activities that contribute to the scientific and operational objectives of the Laboratory are carried out in accordance with the requirements of the LBL Operating and Assurance Program [LBL, 1993]. Conduct of operations and research activities at the ALS are subject to the provisions of the LBL program. In addition, the ALS has developed a facility quality-assurance program that specifically applies to the conduct of its accelerator operations and research activities [ALS, 1993b].

7.1 LBL Operating and Assurance Program

The LBL Operating and Assurance Program (OAP) is administered by the Group Leader, Quality Assurance/Conduct of Operations in the Office of Assessment and Assurance. The OAP is a management system and set of activities designed to

- Maintain the level of performance necessary to achieve LBL's programmatic and administrative objectives effectively and safely through the application of quality-assurance and related conduct-of-operations and maintenance-management principles.

- Implement an LBL management philosophy that supports and encourages continual improvement in performance and quality at the Laboratory.

- Provide a management system that permits an integrated approach to compliance with applicable related regulatory requirements and DOE orders

The requirements specified by the OAP are intended to meet the requirements of DOE Order 5700.6C Quality Assurance [DOE, 1991c]. The OAP also contains management-system elements of DOE Orders 5480.19 Conduct of Operations Requirements for DOE Facilities [DOE, 1990b] and 4430.4A Maintenance Management Program [DOE, 1991d], where appropriate, and is meant to integrate these elements into the overall LBL approach to Laboratory management.

The requirements of the OAP apply to LBL employees and organizations and to contractors and facility users as managed by their LBL sponsors. The requirements are also applicable to external vendors and suppliers as specified in procurement documents and contracts. It is line management's responsibility to plan for and achieve compliance with the requirements and to provide sufficient resources to accomplish the OAP objectives.

7.2 ALS Quality Assurance Program

The ALS Quality Assurance Program (QAP) reflects the LBL philosophy for meeting the requirements of DOE Orders 5700.6C and 5480.19. Under the QAP, the ALS goals are to (1) apply resources efficiently to activities, (2) ensure that ALS facilities are operated in a manner that protects the environment and assures the health and safety of both the public and LBL employees, and (3) eliminate unproductive activities that are costly or unnecessarily burdensome. The Quality Assurance Officer (QAO) assists ALS staff in implementing the requirements of the QAP.

The QAP comprises five elements. These elements reflect a "plan-do-check-act" logic to quality assurance as suggested by the following table:

	Element
Plan	1. Organization
Do	2. Staff selection, proficiency and training
	3. Work processes
	4. Document management
Check/act	5. Performance assessment and improvement

Not all activities have the same effect on health and safety, environmental protection, or programmatic objectives. For this reason, the ALS uses a graded approach to determine the applicability of QAP requirements to each activity and the degree to which the requirements should be enforced. The objective of the ALS graded approach is to ensure that activities with quality-assurance implications are managed through adequate systems that are commensurate with the scale, cost, complexity, and hazards of the work being performed. Considerations in making these determinations include:

- public health and safety,
- researcher health and safety,
- environmental protection,
- compliance with regulations,
- ALS mission and programmatic goals,
- protection of LBL cost/investment, and
- impact on scientific results.

Cognizant ALS engineers and line managers are responsible for identifying activities that are subject to the QAP requirements and for carrying out the analyses to justify the degree to which requirements should be enforced. The role of the QAO is to consult with cognizant personnel concerning quality-assurance issues and to assess adherence to quality-assurance principles.

SECTION 8. ENVIRONMENTAL MONITORING PROGRAM

8.1 Environmental Compliance

ALS operations adhere to DOE orders and to federal, state, and local regulations applicable to environmental protection. DOE orders applicable to activities with potential environmental consequences include 5400.1 General Environmental Protection Program, 5400.5 Radiation Protection of the Public and the Environment [DOE, 1990a] , 5480.1B Environment, Safety, and Health Program for DOE Operations [DOE, 1986b], 5480.2 Hazardous and Radioactive Waste Management [DOE, 1992b], 5480.4 Environmental Protection, Safety, and Health Protection Standards {DOE, 1991e], and 5480.12 General Environmental Protection Program Requirements [DOE, 1992c].

8.1.1 National Environmental Policy Act (NEPA)

ALS activities are subject to the requirements of the National Environmental Policy Act in accordance with DOE Order 5440.1C National Environmental Policy Act [DOE, 1985]. Environmental studies and documentation for the ALS are complete. The principal environmental documents are the Environmental Assessment [DOE, 1989] and the Findings of No Significant Impact.

The original ALS project scope assumed that significant portions of the then existing 184-Inch Cyclotron and its shielding would be reused. LBL prepared an environmental evaluation of the original project, which resulted in a June 1987 DOE-SF Memorandum to File [Neely 1987] stating that the project has "clearly insignificant impact."

In October 1987, decommissioning and removal of the 184-Inch Cyclotron was authorized. In an April 1988 memorandum, DOE/EH-1 requested that an environmental assessment (EA) be prepared for the project. The EH-1 memorandum cited the increased project scope and a lack of depth in the earlier LBL environmental evaluation as the bases for the request. An EA was prepared and received S-1 concurrence and EH-1 approval. A Finding of No Significant Impact was issued in August 1989 [Brush, 1989].

A subsequent minor project change added a cooling tower, chiller plant, and associated piping to the project scope. This modification was found to have insignificant impact, and Memorandum to File on the change was issued in September 1990 [Decker, 1990].

8.1.2 Prevention of Significant Deterioration (PSD)

The ALS is located in the San Francisco Bay Area Air Basin, which is considered by the U.S. Environmental Protection Agency (EPA) to be an attainment area for nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). The EPA has not yet classified the air basin with respect to suspended particulate matter less than 10 microns in diameter (PM10). Emissions of NO_2 and SO_2 from the ALS would be generated primarily by fuel combustion (e.g., in boiler operation). These emissions would not cause PSD threshold levels established by the Bay Area Air Quality Management District (BAAQMD) to be exceeded and, therefore, would not trigger PSD review requirements by the BAAQMD.

8.1.3 California Clean Air Act

To conform with the California Clean Air Act (CCCA), the BAAQMD has revised its new source-review rules to achieve the goal of "no net increase" in emissions of nonattainment pollutants. The BAAQMD requires: (1) emission offsets if emissions of organic compounds, nitrogen oxides, or PM10 exceed the threshold amounts and (2) the best available control technology (BACT) for sources that emit criteria pollutants in excess of threshold amounts. The ALS will not result in the emission of any criteria pollutants in excess of threshold amounts that would trigger emission-offset or BACT requirements.

8.1.4 DOE Environmental Orders 5400.1 and 5400.5

Preoperational surveys conducted in accordance with DOE Orders 5400.1 and 5400.5 will not be required because the ALS occupies a site that is already being monitored by ongoing environmental and radiation-protection programs. The programs conform with DOE Orders 5400.1 and 5400.5 and include the following elements: (1) sampling of workplace and effluent air in all areas where significant quantities of radionuclides are handled, (2) continuous monitoring of penetrating radiation at four perimeter stations and in each major accelerator complex, (3) sampling of sewer outfalls, (4) daily wastewater sampling for chemicals (and metals), (5) on-site and off-site air sampling, (6) sampling of rainfall and dry deposition, and (7) groundwater sampling. The monitoring programs will continue when the ALS is operational.

8.1.5 National Pollutant Discharge Elimination Systems (NPDES)

LBL has submitted a Notice of Intent to the State Water Resources Control Board (part of the California Environmental Protection Agency—formerly the Department of Health Services) for inclusion in the California General Industrial Storm Water Permit. This permit is designed to comply with the recent amendments to the federal Clean Water Act that regulate storm-water runoff. The ALS is included in the LBL submission.

8.2 Existing Permits

8.2.1 Air Emissions

The BAAQMD has issued permits to LBL for such emission sources as solvent cleaning; machine shop, carpentry, and painting operations; and vacuum coating. The ALS would be considered a "new source" and would require a separate permit if there were any emissions greater than threshold amounts established by the BAAQMD.

A BAAQMD permit to operate may be required for the ALS for future solvent-wipe-cleaning operations, depending on the quantity of solvent cleaner used. When these operations are further characterized, a BAAQMD permit will be obtained, as necessary.

Vacuum systems in laboratory operations are exempt from the permit requirements provided that they meet two criteria: (1) they are used in connection with other exempt equipment and (2) the vacuum system does not remove or convey air contaminants from other sources. In general, LBL vacuum systems do not have BAAQMD permits.

The heating, ventilation, and air-conditioning system may be included in an existing permit that exempts all LBL boilers from BAAQMD emission-control requirements. The BAAQMD regulations for boilers are being revised and may remove the LBL exemption in the future, in which case, boilers for the ALS could require separate permits. LBL will coordinate with BAAQMD on this matter.

8.2.2 Water Consumption

The State of California currently does not require permits for water consumption.

8.2.3 Wastewater Discharge

The East May Municipal Utility District (EBMUD) has issued a site-wide wastewater discharge permit that would also cover the ALS. The ALS will not generate wastewater streams that would require additional pretreatment and, consequently, associated pretreatment permits from EBMUD.

8.2.4 Hazardous Waste Generation and Discharge

Hazardous waste generated at the ALS will be handled and disposed of in accordance with EPA hazardous waste regulations [EPA, 1987] and with LBL procedures for hazardous waste, as enumerated in the Guidelines for Generators of Hazardous Chemical Waste at LBL and Guidelines for Generators of Radioactive and Mixed Waste at LBL [LBL, 1991b]. Small quantities of hazardous waster will be stored at satellite accumulation areas at the ALS at the various points of waste generation. Storage quantities at the ALS satellite waste-accumulation areas will not exceed LBL (and regulatory) limits. Following LBL procedures, waste will periodically be transferred from satellite accumulation areas to the LBL Hazardous Waste Handling Facility (HWHF). Permits are not required by the state or the EPA for satellite accumulation areas. LBL is in the process of renewing its permit from the California EPA to operate the HWHF.

8.2.5 Underground Tanks

There will be no underground tanks constructed as part of the ALS.

SECTION 9. DECOMMISSIONING AND DECONTAMINATION PLAN

The life of the ALS will be 20 years or longer. Operation of the ALS will produce no long-lived radioactive products. Chemicals and other hazardous materials will be similar to those of other general laboratory facilities. No special decommissioning or decontamination procedures will be necessary.

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SECTION 11. APPENDICES

Appendix 1

Operational Procedures

Light Source Procedures

LIGHT SOURCE PROCEDURES

LSP	Rev	Scheduled Review	Title/Notes	Superceded by	Issue Date	Author Checker Approver
002	5		Injector Interlock Testing Procedure	EC 02-02	10/15/91	Ritchie Massoletti Lancaster
003	5		Injector Controlled Area Search and Secure Procedures	OP 02-07	03/09/92	Massoletti Kim Jackson
006	1		Injector S-Band Modulator (Local Control) Startup and Shutdown Check List	RF 02-01	10/25/91	Massoletti Brokloff Lancaster
007	1	**04/02/93**	**Electron Gun Enclosure Securing Procedure**		04/02/92	Massoletti Brokloff Jackson
008	1		Light Source Procedure Document Control	ALS 16-01	11/01/91	Jackson Marx Marx
009	0		Training and Certification	OP 05-01	02/14/91	Jackson Marx Marx
010	0	**02/27/93**	**Electron Gun Cathode Activation and Testing Procedure**		02/15/91	Massoletti Taylor Taylor
011	0		Electron Gun High Voltage Conditioning Procedure	Draft RF 02-03	02/15/91	Massoletti Taylor Taylor

012	0		Electron Gun Bakeout Procedure	RF 02-02	02/11/91	Massoletti Taylor Taylor
014	0	**09/11/93**	**Electron Gun Cathode Installation and Preparation Procedure**		03/25/91	Massoletti Catalano Taylor
015	3		Injector Authorized Persons List	ALS 02-01	05/08/92	Atkin Massoletti Jackson
016	4		Injector Commissioning Trainee Startup Checklist	Draft OP 02-06	01/08/92	Massoletti Kim Jackson
017	2	**10/28/92**	**Injector Commissioning Trainee Shutdown Checklist**		10/21/91	Massoletti Brokloff Jackson
018	1	**01/06/94**	**Frame Grabber Instructions**		01/06/93	Meaney Massoletti Kim
019	2	**11/01/93**	**Injector Emergency Shutdown Procedure**		10/20/92	Massoletti Brokloff Jackson
020	0		Engineering Check-Out Interlock Bypass Procedure	ALS 01-02 EE 01-01	05/03/91	Taylor Massoletti Lancaster
021	1	**09/28/93**	**Booster RF Power Systems Operating Procedures**		09/23/92	Taylor Massoletti Lancaster
022	2	**09/23/93**	**Accelerator Controlled-Access Procedure** Needs work, per D. Massoletti		09/23/92	Massoletti Kim Jackson

023	3	**10/15/93**	**Accelerator Initial-Operation Radiation Safety Check List**		10/15/92	Massoletti Keller Jackson
025	3	**06/04/93**	**Booster Kicker Magnet Systems**		05/26/92	Massoletti Peterson Stover
026	0	**09/02/93**	**Commissioning Phase Control System Operating Procedures**	DRAFT CS 02-02	06/04/91	Massoletti Selph Jackson
028	1		Booster Magnet Turn On, Turn Off, Procedure (for Injector Studies)	Obsolete	11/27/91	Kim Massoletti T. Jackson
029	0	**07/1592**	**Accelerator Systems Scheduled Electrical Power Outage Procedure** Rev 1 draft in progress - C. Hauck. Dexter has markups. Scheduled Rev should be 6 mos.		07/12/91	Massoletti Brokloff Jackson
030	3	**09/25/93**	**Accelerator Commissioning Operations Log Keeping**		09/25/92	Brokloff Massoletti Jackson
031	0	**11/08/92**	**Injector Commissioning Beam Operation Disabling Procedure**		11/08/92	Massoletti Kim Jackson
033	0	**09/25/93**	**Accelerator Operations Shift Turnover** Make applicable to storage ring.		03/12/92	Massoletti Brokloff Jackson
034	0	**06/05/93**	**Injector Bump & Septum Magnet Operating Procedures** Equivalent needed for storage ring.		05/27/92	Stover Massoletti Jackson
035			Radiation Safety Shielding Control Procedure	OP 02-04		Collins

036	0		Undulator Safety LockOut TagOut Procedures	ID 09-01	05/04/92	Chin Hoyer Hoyer
037	0	**10/15/93**	**Area Radiation Monitor Setpoint Changing Procedure**		11/04/92	Collins Brokloff Jackson
038	0	**11/04/93**	**Area Radiation Monitor Changeout Procedure**		11/04/92	Collins Nolan Jackson
039	0		Storage Ring Search & Secure Procedure	OP 02-07		Massoletti Jackson Kincaid
040	0	**02/01/94**	**Storage Ring RF Power System Operating Procedure**		01/29/93	B Taylor J Julian H Lancaster

Conduct of Operations Procedures

Conduct of Operations Procedures Plan Summary

		Procedure Title	Preparer	Reviewer	Rev.	S	E	P	C	draft	review	final	exp.
ALS 01	01	Training Documentation for Procedures	Jones, R	Perdue, G	1	S				11/18/92	6/29/93	6/30/93	06/29/96
ALS 01	02	Proc. for Temporary Bypass of Personnel	Jones, R	Lancaster,Miller,Rit	0	S		P		4/5/93	4/8/93	4/9/93	04/08/96
ALS 02	01	Accelerator Authorized Persons List	Jones, R	Miller, R	1	S				2/10/93	4/20/93	4/20/93	04/19/96
ALS 09	01	Electrical Lockout/Tagout Supplementary	Gregor,Jones	Miller,Wong	1	S				7/14/93	7/14/93	7/15/93	07/14/96
ALS 16	01	ALS Proc. Format & Guidelines	Jones, R	Perdue, G	2	S	E	P		11/19/92	6/29/93	6/30/93	06/29/96
BL 08	01	Beamline Key-enable for ALS Oper. Coord.	Warwick, T	Padmore, H	0	S		P	C	5/10/93	10/1/93	10/4/93	10/03/96
BL 08	02	Beamline Shutter Procedure	Warwick, T	Padmore, H	0	S		P	C	6/10/93	10/1/93	10/4/93	10/03/96
BL 08	03	Venting Beamlines to Avoid Overpressure	DiGennaro, D	Padmore, H	0	S		P		9/13/93	9/29/93	9/30/93	09/29/96
BL 08	04	Front End Inspection by ALS Operations	Warwick,Woolfe	Miller,Thatcher	0	S		P	C	8/11/93	8/24/93	8/27/93	08/26/96
BL 08	05	Beamline Hutch Access Procedure	Ritchie,Warwick	Heimann,Miller,Pa	0	S		P		9/29/30	10/1/93	10/4/93	10/03/96
BL 08	06	Low Current Operation Proc. for Beamline 7.0	Jackson, A	Miller,Ritchie,Warwi	0	S		P		10/4/93			
CS 02	01	Control Sys. Software Testing of SR Mag.	Meaney, D	Jackson, T	0	S		P		12/8/92	12/8/92	12/8/92	12/08/95
CS 02	02	Testing Remote Control Software	Young, J	Portman,Timossi	0	S		P		8/25/93			
EC 02	01	SR Vacuum Sys. Bakeout & Outage & Transf.	Downes, T	Ritchie, A	1	S		P		12/21/92	9/24/93	9/28/93	09/27/96
EC 02	02	ALS Radiation Interlock System Testing	Ritchie, A	Oldfather, D	4	S		P	C	2/23/93	3/31/93	3/31/93	03/30/96
EC 02	03	SR01 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	12/10/92	2/8/93	2/8/93	02/08/96
EC 02	04	SR02 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	05	SR03 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	06	SR04 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	07	SR05 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	08	SR06 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	09	SR07 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	10	SR08 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	11	SR09 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	12	SR10 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	13	SR11 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	14	SR12 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EE 01	01	Equipment Interlock Bypass Procedure	Gregor, J	Nolan, M	0	S		P		4/6/93	4/7/93	4/7/93	04/06/96
EE 02	01	Proc. for Design & Modification of Pers.	Jones, R	Lancaster, Ritchie	0	S		P		2/16/93	2/23/93	2/23/93	02/23/96
EG 02	01	High Voltage (High-Pot) Pretest Check List	Jones, R	Taylor, B	0	S			C	12/3/92	2/2/93	2/4/93	02/04/96

Procedure impacts are indicated: S = Safety, E = Environment, P = Program, C = indicates the procedure is a checklist, d = deleted

Conduct of Operations Procedures Plan Summary

		Procedure Title	Preparer	Reviewer	Rev.	S	E	P	C	draft	review	final	exp.
EM 01	01	Selection Criteria for ALS EM Section	Lancaster, H	Gregor,Jackson T	0			P		9/9/93	9/23/93	9/23/93	09/22/96
EM 01	02	Specific Training for ALS EM Section	Lancaster, H	Gregor, J	0	S		P		9/28/93			
EM 02	01	Installation of GPIB-SBX into ILC IIB	Chin, M	Henson,Perry	0			P		4/21/93			
EM 02	02	Thyratron Bias Chassis Removal &	Peterson, D	Stover,Mueller	0	S		P		4/22/93	6/14/92	6/15/92	06/15/95
EM 02	03	Intelligent Logic Controller (ILC) Digital	Chin,Hauck	Daly, S	0			P		4/27/93	7/8/93	7/12/93	07/11/96
EM 02	04	Testing the SR Direct Current Current Transf.	Hinkson, J	Nolan, M	0	S		P		5/6/93	5/10/93	5/10/92	05/10/95
EM 02	05	Techron 7521 Power Supply Annual Prev.	Luchini, K	Gregor, Miller	0	S		P	C	6/16/93			
EM 02	06	Kepco Power Supply Annual Prev.	Luchini, K	Gregor, Miller	0	S		P	C	6/16/93			
EM 02	07	EMI 12T220 Power Supply Annual Prev.	Luchini, K	Gregor, Miller	0	S		P	C	6/18/93			
EM 02	08	Inverpower 550 Series Power Supply Annual	Luchini, K	Gregor, Miller	0	S		P	C	6/28/93			
EM 02	09	Operation of PC Software (Dbchan) for	Young, J	Mueller, Nolan	0			P		6/17/92	7/2/93	7/20/93	07/19/96
EM 09	01	Booster Ring Injec. Kicker Mag. (BR-1) LOTO	Jones, R	Gershon, Gregor	2	S		P		5/25/93	9/23/93	9/23/93	09/22/96
EM 09	02	De-energizing Perkin Elmer Ion Pumps for	Jones, R	Gregor, J	0	S		P		3/10/93	3/30/93	3/30/93	03/29/96
EM 09	03	De-energizing Varian Ion Pumps for	Jones, R	Julian, J	0	S		P		4/21/93	4/21/93	4/22/93	04/21/96
EM 09	04	Booster Ring Extraction Kicker Magnet LOTO	Jones, R	Gershon, Gregor	1	S		P		5/25/93	9/22/93	9/23/93	09/22/96
HP 02	01	ALS Controlled Area Visitor Sign-In	Collins,Jones	Miller,Kloepping	0	S		P		4/29/93	9/13/93	9/14/93	09/13/96
ID 02	01	Undulators IDA, IDB, IDC Maintenance Proc.	Chin, J	Gath	0	S		P	C	9/15/93			
ID 09	01	Undulators IDA, IDB, IDC LOTO Procedure	Chin,Hoyer	Gath,Gershon,Port	0	S		P		9/7/93			
MS 01	01	Magnet Temp. Monitoring during Bakeout	Tanabe, J	Henderson, T	0	S		P	C	5/7/93	7/2/93	7/2/93	07/01/96
MS 02	01	TECHRON 7521 Pwr. Sup. Amp. Ann. Chk.	Miller, R	Nolan, M	0	S		P	d	11/13/92	12/7/92	12/8/92	12/08/95
MT 02	01	LS-160 LN Dewar inside ALS Enclosed Areas	Perdue, G	Davis,P & Wong,W	0	S	E			5/5/93	6/7/93	6/7/93	06/06/96
MT 02	02	Storage Ring Sector Bakeout Procedures	Thomson, J	Wong, W	0	S		P		9/23/92			
MT 02	03	Sector Chamber Bakeout and Conditioning	Thomson, J	Wong, W	0	S		P		9/23/92			
MT 09	01	Group LOTO Admin. Procedure for ALS MT's	Wong, W	Gershon, Gregor	0	S				7/19/92	8/5/93	8/6/93	08/05/96
OP 02	01	Hinged Shielding Door Operation	Reimers, D	Miller, R	Dft	S		P		1/5/93			
OP 02	02	Tour of the ALS Facility	Miller, R	Brokloff,Byrne,Hau	0	S		P		1/11/93	2/22/93	2/23/93	02/23/96
OP 02	04	Shielding Control Procedure	Collins, H	Jackson,Stevenso	0	S		P		2/8/93	2/19/92	2/22/93	02/22/96
OP 02	05	SR Bump & Septum Magnet Operating Proc.	Stover,Daly	Brokloff,Byrne	0	S		P		3/18/93	6/11/93	6/16/93	06/15/96
OP 02	06	Accelerator Startup Checklist	Massoletti, D	Brokloff,Hauck,Byr	0	S		P	C	4/2/93			
OP 02	07	Accelerator Search & Secure Procedure	Daly, S	All Operators	0	S		P		5/28/93	8/26/93	8/31/93	08/30/96

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10/5/93

Conduct of Operations Procedures Plan Summary

		Procedure Title	Preparer	Reviewer	Rev.	S	E	P	C	draft	review	final	exp.
OP 05	01	Training and Certification	Jones, R	Miller, R	0	S		P		3/31/93	4/8/93	4/9/93	04/08/96
PS 02	01	Testing of Major SR Magnet Power Supplies	Jones, R	Jackson, T	0	S		P		3/1/93	3/2/93	3/2/93	03/01/96
RF 02	01	Injector S-Band Mod. Startup & Shutdown	Jones, R	Taylor, B	0	S		P	C	1/4/93	1/20/93	1/21/93	01/21/96
RF 02	02	Electron Gun Bakeout Procedure	Massoletti, D	Baptiste, K	0	S		P		3/15/93	4/6/93	4/6/93	04/05/96
RF 02	03	Electron Gun HV Conditioning Procedure	Massoletti, D	Baptiste, K	0	S		P		3/15/93			
RF 02	04	Startup of the Storage Ring RF Cooling Sys.	Taylor, B	Hauck, Julian	0	S		P		7/12/93	9/23/93	9/23/93	09/22/96
RF 02	05	Shutdown of the Storage Ring RF Cooling	Taylor, B	Hauck, Julian	0	S		P		7/28/93	9/23/93	9/23/93	09/22/96
RF 02	06	Startup of SR High Power RF Amplifier	Taylor, B		0	S		P		8/15/93			
RF 02	07	Shutdown of SR High Power RF Amplifier	Taylor, B		0	S		P		8/15/93			
RF 02	08	Interlock Status Analysis of SR RF System	Taylor, B		0	S		P		8/30/93			
RF 02	09	Tuning SR RF Cavities & Setting Power Level	Taylor, B		0	S		P		8/30/93			
RF 02	10	Linac Maintenance	Taylor, B		0	S		P		10/1/93			
RF 02	11	Booster RF Maintenance	Taylor, B		0	S		P		10/1/93			
RF 02	12	SR RF Maintenance	Taylor, B		0	S		P		10/1/93			
RF 09	01	Booster Ring RF Cavity LOTO Procedure	Taylor, B	Gregor, Julian	0	S		P		6/1/93	6/8/93	6/8/93	06/07/96
SA 08	01	Precision Sight Level Field Calibration	DeMarco, R		0			P		5/3/93			
SA 08	02	Theodolite Index Error Correction	DeMarco, R		0			P		5/3/93			
SA 08	03	Theodolite Calibration Shipping Procedure	DeMarco, R		0			P		9/1/93			
SA 08	04	Booster Girder Fiducialization	DeMarco, R		0			P		9/1/93			
SA 08	05	Survey of Booster Magnets/Girder	DeMarco, R		0			P		9/1/93			
SA 08	06	Survey of Booster Girder & Magnets/Monmts.	DeMarco, R		0			P		9/1/93			
SA 08	07	Storage Ring Girder Fiducialization	DeMarco, R		0			P		9/1/93			
SA 08	08	Survey of Storage Ring Magnets/Girder	DeMarco, R		0			P		9/1/93			
SA 08	09	Survey of SR Girder & Magnets/Monuments	DeMarco, R		0			P		9/1/93			
SA 08	10	Optical Transit Field Calibration	DeMarco, R		0			P		7/1/94			
SA 08	11	ECDS Hidden Point Rod Survey	DeMarco, R		0			P		7/1/94			
SA 08	12	Individual Components Patch-In Surveys	DeMarco, R		0			P		7/1/94			
SA 08	13	Elevation Stave Calibration	DeMarco, R		0			P		7/1/94			
SA 08	14	Monument Use	DeMarco, R		0			P		7/1/94			
SA 08	15	Monument Elevation (In Level) Survey	DeMarco, R		0			P		7/1/94			

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10/5/93

Conduct of Operations Procedures Plan Summary

		Procedure Title	Preparer	Reviewer	Rev.	S	E	P	C	draft	review	final	exp.
SA 08	16	Setting Out Stands	DeMarco, R		0			P		7/1/94			
SA 08	17	Survey of Booster Straight Sections	DeMarco, R		0			P		7/1/94			
SA 08	18	Alignment:Booster Gird. to Monmts (Mag. not	DeMarco, R		0			P		7/1/94			
SA 08	19	Alignment:Booster Magnets to Girder	DeMarco, R		0			P		7/1/94			
SA 08	20	Alignment:Booster Gird. to Monmts (Mag. Inst)	DeMarco, R		0			P		7/1/94			
SA 08	21	Alignment:Booster Straight Sections	DeMarco, R		0			P		7/1/94			
SA 08	22	QA Survey of SR Vacuum Chamber	DeMarco, R		0			P		7/1/94			
SA 08	23	Survey of SR Vacuum Chamber/Girder	DeMarco, R		0			P		7/1/94			
SA 08	24	Survey of SR Straight Section	DeMarco, R		0			P		7/1/94			
SA 08	25	Alignment:SR Vac. Chamber to Girder (Rough)	DeMarco, R		0			P		7/1/94			
SA 08	26	Alignment:SR Vac. Chamber to Girder (Final)	DeMarco, R		0			P		7/1/94			
SA 08	27	Alignment:SR Gird./Cham.to Monmts(Mag. not	DeMarco, R		0			P		7/1/94			
SA 08	28	Alignment:SR Gird/Cham.to Monmts(Mag.Inst)	DeMarco, R		0			P		7/1/94			
SA 08	29	Alignment:SR Magnets to Girder	DeMarco, R		0			P		7/1/94			
SA 08	30	Alignment:SR Girder to Monmts(Mag.Installed)	DeMarco, R		0			P		7/1/94			
SA 08	31	Alignment:SR Vac. Cham. to Monmts (Optical	DeMarco, R		0			P		7/1/94			
SA 08	32	Alignment:SR Straight Sections	DeMarco, R		0			P		7/1/94			
SA 08	33	Alignment:Beamline Components	DeMarco, R		0			P		7/1/94			
US 02	01	User Safety Training	Jones, R	Johnson, Perdue	0	S	E	P		1/27/93	2/1/93	2/1/93	02/01/96
US 02	02	User Facility Acess	Jones, R	Johnson, Perdue	0	S		P		1/27/93	2/1/93	2/1/93	02/01/96
US 02	03	Experiment Form for ALS Users	Perdue, G	Johnson, P	1	S	E	P		2/2/93	9/7/93	9/16/93	09/15/96
US 02	05	Experiment Summary Sheet for ALS Users	Jones, R	Johnson, Perdue	1	S	E	P		1/27/93	9/7/93	9/16/93	09/15/96
US 02	06	Chemical Handling for (ALS) Users	Perdue, G	Johnson, P	1	S	E	P		2/2/93	9/7/93	9/16/93	09/15/96
US 02	07	ALS Post-Experimental Form	Jones, R	Johnson, Perdue	1	S	E	P		1/27/93	9/7/93	9/16/93	09/15/96
US 02	08	Experiment Modification Form	Jones, R	Johnson, Perdue	1	S	E	P		1/28/93	9/7/93	9/7/93	09/06/96
US 02	09	ALS Experiment Form Renewal	Jones, R	Schlachter, F	0	S	E	P		4/28/93	9/7/93	9/16/93	09/15/96
VS 02	01	Pneumatic Vacuum Valve Safety	Jones, R	Kennedy, K	0	S		P		3/11/93	3/15/93	3/15/93	03/14/96

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PUB-720/3-93

SECTION 11. APPENDICES

Appendix 1

Operational Procedures

Light Source Procedures

LIGHT SOURCE PROCEDURES

LSP	Rev	Scheduled Review	Title/Notes	Superceded by	Issue Date	Author Checker Approver
002	5		Injector Interlock Testing Procedure	EC 02-02	10/15/91	Ritchie Massoletti Lancaster
003	5		Injector Controlled Area Search and Secure Procedures	OP 02-07	03/09/92	Massoletti Kim Jackson
006	1		Injector S-Band Modulator (Local Control) Startup and Shutdown Check List	RF 02-01	10/25/91	Massoletti Brokloff Lancaster
007	1	**04/02/93**	**Electron Gun Enclosure Securing Procedure**		04/02/92	Massoletti Brokloff Jackson
008	1		Light Source Procedure Document Control	ALS 16-01	11/01/91	Jackson Marx Marx
009	0		Training and Certification	OP 05-01	02/14/91	Jackson Marx Marx
010	0	**02/27/93**	**Electron Gun Cathode Activation and Testing Procedure**		02/15/91	Massoletti Taylor Taylor
011	0		Electron Gun High Voltage Conditioning Procedure	Draft RF 02-03	02/15/91	Massoletti Taylor Taylor

012	0		Electron Gun Bakeout Procedure	RF 02-02	02/11/91	Massoletti Taylor Taylor
014	0	**09/11/93**	**Electron Gun Cathode Installation and Preparation Procedure**		03/25/91	Massoletti Catalano Taylor
015	3		Injector Authorized Persons List	ALS 02-01	05/08/92	Atkin Massoletti Jackson
016	4		Injector Commissioning Trainee Startup Checklist	Draft OP 02-06	01/08/92	Massoletti Kim Jackson
017	2	**10/28/92**	**Injector Commissioning Trainee Shutdown Checklist**		10/21/91	Massoletti Brokloff Jackson
018	1	**01/06/94**	**Frame Grabber Instructions**		01/06/93	Meaney Massoletti Kim
019	2	**11/01/93**	**Injector Emergency Shutdown Procedure**		10/20/92	Massoletti Brokloff Jackson
020	0		Engineering Check-Out Interlock Bypass Procedure	ALS 01-02 EE 01-01	05/03/91	Taylor Massoletti Lancaster
021	1	**09/28/93**	**Booster RF Power Systems Operating Procedures**		09/23/92	Taylor Massoletti Lancaster
022	2	**09/23/93**	**Accelerator Controlled-Access Procedure** Needs work, per D. Massoletti		09/23/92	Massoletti Kim Jackson

023	3	**10/15/93**	**Accelerator Initial-Operation Radiation Safety Check List**		10/15/92	Massoletti Keller Jackson
025	3	**06/04/93**	**Booster Kicker Magnet Systems**		05/26/92	Massoletti Peterson Stover
026	0	**09/02/93**	**Commissioning Phase Control System Operating Procedures**	DRAFT CS 02-02	06/04/91	Massoletti Selph Jackson
028	1		Booster Magnet Turn On, Turn Off, Procedure (for Injector Studies)	Obsolete	11/27/91	Kim Massoletti T. Jackson
029	0	**07/1592**	**Accelerator Systems Scheduled Electrical Power Outage Procedure** Rev 1 draft in progress - C. Hauck. Dexter has markups. Scheduled Rev should be 6 mos.		07/12/91	Massoletti Brokloff Jackson
030	3	**09/25/93**	**Accelerator Commissioning Operations Log Keeping**		09/25/92	Brokloff Massoletti Jackson
031	0	**11/08/92**	**Injector Commissioning Beam Operation Disabling Procedure**		11/08/92	Massoletti Kim Jackson
033	0	**09/25/93**	**Accelerator Operations Shift Turnover** Make applicable to storage ring.		03/12/92	Massoletti Brokloff Jackson
034	0	**06/05/93**	**Injector Bump & Septum Magnet Operating Procedures** Equivalent needed for storage ring.		05/27/92	Stover Massoletti Jackson
035			Radiation Safety Shielding Control Procedure	OP 02-04		Collins

036	0		Undulator Safety LockOut TagOut Procedures	ID 09-01	05/04/92	Chin Hoyer Hoyer
037	0	**10/15/93**	**Area Radiation Monitor Setpoint Changing Procedure**		11/04/92	Collins Brokloff Jackson
038	0	**11/04/93**	**Area Radiation Monitor Changeout Procedure**		11/04/92	Collins Nolan Jackson
039	0		Storage Ring Search & Secure Procedure	OP 02-07		Massoletti Jackson Kincaid
040	0	**02/01/94**	**Storage Ring RF Power System Operating Procedure**		01/29/93	B Taylor J Julian H Lancaster

Conduct of Operations Procedures

Conduct of Operations Procedures Plan Summary

		Procedure Title	Preparer	Reviewer	Rev.	S	E	P	C	draft	review	final	exp.
ALS 01	01	Training Documentation for Procedures	Jones, R	Perdue, G	1	S				11/18/92	6/29/93	6/30/93	06/29/96
ALS 01	02	Proc. for Temporary Bypass of Personnel	Jones, R	Lancaster,Miller,Rit	0	S		P		4/5/93	4/8/93	4/9/93	04/08/96
ALS 02	01	Accelerator Authorized Persons List	Jones, R	Miller, R	1	S				2/10/93	4/20/93	4/20/93	04/19/96
ALS 09	01	Electrical Lockout/Tagout Supplementary	Gregor,Jones	Miller,Wong	1	S				7/14/93	7/14/93	7/15/93	07/14/96
ALS 16	01	ALS Proc. Format & Guidelines	Jones, R	Perdue, G	2	S	E	P		11/19/92	6/29/93	6/30/93	06/29/96
BL 08	01	Beamline Key-enable for ALS Oper. Coord.	Warwick, T	Padmore, H	0	S		P	C	5/10/93	10/1/93	10/4/93	10/03/96
BL 08	02	Beamline Shutter Procedure	Warwick, T	Padmore, H	0	S		P	C	6/10/93	10/1/93	10/4/93	10/03/96
BL 08	03	Venting Beamlines to Avoid Overpressure	DiGennaro, D	Padmore, H	0	S		P		9/13/93	9/29/93	9/30/93	09/29/96
BL 08	04	Front End Inspection by ALS Operations	Warwick,Woolfe	Miller,Thatcher	0	S		P	C	8/11/93	8/24/93	8/27/93	08/26/96
BL 08	05	Beamline Hutch Access Procedure	Ritchie,Warwick	Heimann,Miller,Pa	0	S		P		9/29/30	10/1/93	10/4/93	10/03/96
BL 08	06	Low Current Operation Proc. for Beamline 7.0	Jackson, A	Miller,Ritchie,Warwi	0	S		P		10/4/93			
CS 02	01	Control Sys. Software Testing of SR Mag.	Meaney, D	Jackson, T	0	S		P		12/8/92	12/8/92	12/8/92	12/08/95
CS 02	02	Testing Remote Control Software	Young, J	Portman,Timossi	0	S		P		8/25/93			
EC 02	01	SR Vacuum Sys. Bakeout & Outage & Transf.	Downes, T	Ritchie, A	1	S		P		12/21/92	9/24/93	9/28/93	09/27/96
EC 02	02	ALS Radiation Interlock System Testing	Ritchie, A	Oldfather, D	4	S		P	C	2/23/93	3/31/93	3/31/93	03/30/96
EC 02	03	SR01 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	12/10/92	2/8/93	2/8/93	02/08/96
EC 02	04	SR02 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	05	SR03 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	06	SR04 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	07	SR05 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	08	SR06 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	09	SR07 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	10	SR08 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	11	SR09 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	12	SR10 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	13	SR11 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EC 02	14	SR12 Vacuum Test Interlock Procedure	Woolfe, K	Hinkson, J	0	S		P	C	2/5/93	2/8/93	2/8/93	02/08/96
EE 01	01	Equipment Interlock Bypass Procedure	Gregor, J	Nolan, M	0	S		P		4/6/93	4/7/93	4/7/93	04/06/96
EE 02	01	Proc. for Design & Modification of Pers.	Jones, R	Lancaster, Ritchie	0	S		P		2/16/93	2/23/93	2/23/93	02/23/96
EG 02	01	High Voltage (High-Pot) Pretest Check List	Jones, R	Taylor, B	0	S			C	12/3/92	2/2/93	2/4/93	02/04/96

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EM 01	01	Selection Criteria for ALS EM Section	Lancaster, H	Gregor,Jackson T	0			P		9/9/93	9/23/93	9/23/93	09/22/96
EM 01	02	Specific Training for ALS EM Section	Lancaster, H	Gregor, J	0	S		P		9/28/93			
EM 02	01	Installation of GPIB-SBX into ILC IIB	Chin, M	Henson,Perry	0			P		4/21/93			
EM 02	02	Thyratron Bias Chassis Removal &	Peterson, D	Stover,Mueller	0	S		P		4/22/93	6/14/92	6/15/92	06/15/95
EM 02	03	Intelligent Logic Controller (ILC) Digital	Chin,Hauck	Daly, S	0			P		4/27/93	7/8/93	7/12/93	07/11/96
EM 02	04	Testing the SR Direct Current Current Transf.	Hinkson, J	Nolan, M	0	S		P		5/6/93	5/10/93	5/10/92	05/10/95
EM 02	05	Techron 7521 Power Supply Annual Prev.	Luchini, K	Gregor, Miller	0	S		P	C	6/16/93			
EM 02	06	Kepco Power Supply Annual Prev.	Luchini, K	Gregor, Miller	0	S		P	C	6/16/93			
EM 02	07	EMI 12T220 Power Supply Annual Prev.	Luchini, K	Gregor, Miller	0	S		P	C	6/18/93			
EM 02	08	Inverpower 550 Series Power Supply Annual	Luchini, K	Gregor, Miller	0	S		P	C	6/28/93			
EM 02	09	Operation of PC Software (Dbchan) for	Young, J	Mueller, Nolan	0			P		6/17/92	7/2/93	7/20/93	07/19/96
EM 09	01	Booster Ring Injec. Kicker Mag. (BR-1) LOTO	Jones, R	Gershon, Gregor	2	S		P		5/25/93	9/23/93	9/23/93	09/22/96
EM 09	02	De-energizing Perkin Elmer Ion Pumps for	Jones, R	Gregor, J	0	S		P		3/10/93	3/30/93	3/30/93	03/29/96
EM 09	03	De-energizing Varian Ion Pumps for	Jones, R	Julian, J	0	S		P		4/21/93	4/21/93	4/22/93	04/21/96
EM 09	04	Booster Ring Extraction Kicker Magnet LOTO	Jones, R	Gershon, Gregor	1	S		P		5/25/93	9/22/93	9/23/93	09/22/96
HP 02	01	ALS Controlled Area Visitor Sign-In	Collins,Jones	Miller,Kloepping	0	S		P		4/29/93	9/13/93	9/14/93	09/13/96
ID 02	01	Undulators IDA, IDB, IDC Maintenance Proc.	Chin, J	Gath	0	S		P	C	9/15/93			
ID 09	01	Undulators IDA, IDB, IDC LOTO Procedure	Chin,Hoyer	Gath,Gershon,Port	0	S		P		9/7/93			
MS 01	01	Magnet Temp. Monitoring during Bakeout	Tanabe, J	Henderson, T	0	S		P	C	5/7/93	7/2/93	7/2/93	07/01/96
MS 02	01	TECHRON 7521 Pwr. Sup. Amp. Ann. Chk.	Miller, R	Nolan, M	0	S		P	d	11/13/92	12/7/92	12/8/92	12/08/95
MT 02	01	LS-160 LN Dewar inside ALS Enclosed Areas	Perdue, G	Davis,P & Wong,W	0	S	E			5/5/93	6/7/93	6/7/93	06/06/96
MT 02	02	Storage Ring Sector Bakeout Procedures	Thomson, J	Wong, W	0	S		P		9/23/92			
MT 02	03	Sector Chamber Bakeout and Conditioning	Thomson, J	Wong, W	0	S		P		9/23/92			
MT 09	01	Group LOTO Admin. Procedure for ALS MT's	Wong, W	Gershon, Gregor	0	S				7/19/92	8/5/93	8/6/93	08/05/96
OP 02	01	Hinged Shielding Door Operation	Reimers, D	Miller, R	Dft	S		P		1/5/93			
OP 02	02	Tour of the ALS Facility	Miller, R	Brokloff,Byrne,Hau	0	S		P		1/11/93	2/22/93	2/23/93	02/23/96
OP 02	04	Shielding Control Procedure	Collins, H	Jackson,Stevenso	0	S		P		2/8/93	2/19/92	2/22/93	02/22/96
OP 02	05	SR Bump & Septum Magnet Operating Proc.	Stover,Daly	Brokloff,Byrne	0	S		P		3/18/93	6/11/93	6/16/93	06/15/96
OP 02	06	Accelerator Startup Checklist	Massoletti, D	Brokloff,Hauck,Byr	0	S		P	C	4/2/93			
OP 02	07	Accelerator Search & Secure Procedure	Daly, S	All Operators	0	S		P		5/28/93	8/26/93	8/31/93	08/30/96

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OP 05	01	Training and Certification	Jones, R	Miller, R	0	S		P		3/31/93	4/8/93	4/9/93	04/08/96
PS 02	01	Testing of Major SR Magnet Power Supplies	Jones, R	Jackson, T	0	S		P		3/1/93	3/2/93	3/2/93	03/01/96
RF 02	01	Injector S-Band Mod. Startup & Shutdown	Jones, R	Taylor, B	0	S		P	C	1/4/93	1/20/93	1/21/93	01/21/96
RF 02	02	Electron Gun Bakeout Procedure	Massoletti, D	Baptiste, K	0	S		P		3/15/93	4/6/93	4/6/93	04/05/96
RF 02	03	Electron Gun HV Conditioning Procedure	Massoletti, D	Baptiste, K	0	S		P		3/15/93			
RF 02	04	Startup of the Storage Ring RF Cooling Sys.	Taylor, B	Hauck, Julian	0	S		P		7/12/93	9/23/93	9/23/93	09/22/96
RF 02	05	Shutdown of the Storage Ring RF Cooling	Taylor, B	Hauck, Julian	0	S		P		7/28/93	9/23/93	9/23/93	09/22/96
RF 02	06	Startup of SR High Power RF Amplifier	Taylor, B		0	S		P		8/15/93			
RF 02	07	Shutdown of SR High Power RF Amplifier	Taylor, B		0	S		P		8/15/93			
RF 02	08	Interlock Status Analysis of SR RF System	Taylor, B		0	S		P		8/30/93			
RF 02	09	Tuning SR RF Cavities & Setting Power Level	Taylor, B		0	S		P		8/30/93			
RF 02	10	Linac Maintenance	Taylor, B		0	S		P		10/1/93			
RF 02	11	Booster RF Maintenance	Taylor, B		0	S		P		10/1/93			
RF 02	12	SR RF Maintenance	Taylor, B		0	S		P		10/1/93			
RF 09	01	Booster Ring RF Cavity LOTO Procedure	Taylor, B	Gregor, Julian	0	S		P		6/1/93	6/8/93	6/8/93	06/07/96
SA 08	01	Precision Sight Level Field Calibration	DeMarco, R		0			P		5/3/93			
SA 08	02	Theodolite Index Error Correction	DeMarco, R		0			P		5/3/93			
SA 08	03	Theodolite Calibration Shipping Procedure	DeMarco, R		0			P		9/1/93			
SA 08	04	Booster Girder Fiducialization	DeMarco, R		0			P		9/1/93			
SA 08	05	Survey of Booster Magnets/Girder	DeMarco, R		0			P		9/1/93			
SA 08	06	Survey of Booster Girder & Magnets/Monmts.	DeMarco, R		0			P		9/1/93			
SA 08	07	Storage Ring Girder Fiducialization	DeMarco, R		0			P		9/1/93			
SA 08	08	Survey of Storage Ring Magnets/Girder	DeMarco, R		0			P		9/1/93			
SA 08	09	Survey of SR Girder & Magnets/Monuments	DeMarco, R		0			P		9/1/93			
SA 08	10	Optical Transit Field Calibration	DeMarco, R		0			P		7/1/94			
SA 08	11	ECDS Hidden Point Rod Survey	DeMarco, R		0			P		7/1/94			
SA 08	12	Individual Components Patch-In Surveys	DeMarco, R		0			P		7/1/94			
SA 08	13	Elevation Stave Calibration	DeMarco, R		0			P		7/1/94			
SA 08	14	Monument Use	DeMarco, R		0			P		7/1/94			
SA 08	15	Monument Elevation (In Level) Survey	DeMarco, R		0			P		7/1/94			

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SA 08	16	Setting Out Stands	DeMarco, R		0			P		7/1/94			
SA 08	17	Survey of Booster Straight Sections	DeMarco, R		0			P		7/1/94			
SA 08	18	Alignment:Booster Gird. to Monmts (Mag. not	DeMarco, R		0			P		7/1/94			
SA 08	19	Alignment:Booster Magnets to Girder	DeMarco, R		0			P		7/1/94			
SA 08	20	Alignment:Booster Gird. to Monmts (Mag. Inst)	DeMarco, R		0			P		7/1/94			
SA 08	21	Alignment:Booster Straight Sections	DeMarco, R		0			P		7/1/94			
SA 08	22	QA Survey of SR Vacuum Chamber	DeMarco, R		0			P		7/1/94			
SA 08	23	Survey of SR Vacuum Chamber/Girder	DeMarco, R		0			P		7/1/94			
SA 08	24	Survey of SR Straight Section	DeMarco, R		0			P		7/1/94			
SA 08	25	Alignment:SR Vac. Chamber to Girder (Rough)	DeMarco, R		0			P		7/1/94			
SA 08	26	Alignment:SR Vac. Chamber to Girder (Final)	DeMarco, R		0			P		7/1/94			
SA 08	27	Alignment:SR Gird./Cham.to Monmts(Mag. not	DeMarco, R		0			P		7/1/94			
SA 08	28	Alignment:SR Gird/Cham.to Monmts(Mag.Inst)	DeMarco, R		0			P		7/1/94			
SA 08	29	Alignment:SR Magnets to Girder	DeMarco, R		0			P		7/1/94			
SA 08	30	Alignment:SR Girder to Monmts(Mag.Installed)	DeMarco, R		0			P		7/1/94			
SA 08	31	Alignment:SR Vac. Cham. to Monmts (Optical	DeMarco, R		0			P		7/1/94			
SA 08	32	Alignment:SR Straight Sections	DeMarco, R		0			P		7/1/94			
SA 08	33	Alignment:Beamline Components	DeMarco, R		0			P		7/1/94			
US 02	01	User Safety Training	Jones, R	Johnson, Perdue	0	S	E	P		1/27/93	2/1/93	2/1/93	02/01/96
US 02	02	User Facility Acess	Jones, R	Johnson, Perdue	0	S		P		1/27/93	2/1/93	2/1/93	02/01/96
US 02	03	Experiment Form for ALS Users	Perdue, G	Johnson, P	1	S	E	P		2/2/93	9/7/93	9/16/93	09/15/96
US 02	05	Experiment Summary Sheet for ALS Users	Jones, R	Johnson, Perdue	1	S	E	P		1/27/93	9/7/93	9/16/93	09/15/96
US 02	06	Chemical Handling for (ALS) Users	Perdue, G	Johnson, P	1	S	E	P		2/2/93	9/7/93	9/16/93	09/15/96
US 02	07	ALS Post-Experimental Form	Jones, R	Johnson, Perdue	1	S	E	P		1/27/93	9/7/93	9/16/93	09/15/96
US 02	08	Experiment Modification Form	Jones, R	Johnson, Perdue	1	S	E	P		1/28/93	9/7/93	9/7/93	09/06/96
US 02	09	ALS Experiment Form Renewal	Jones, R	Schlachter, F	0	S	E	P		4/28/93	9/7/93	9/16/93	09/15/96
VS 02	01	Pneumatic Vacuum Valve Safety	Jones, R	Kennedy, K	0	S		P		3/11/93	3/15/93	3/15/93	03/14/96

Procedure impacts are indicated: S = Safety, E = Environment, P = Program, C = indicates the procedure is a checklist, d = deleted

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